TruePosition Indoor Test Report
Wilmington, DE

March 22, 2013

Prepared By:

TechnoCom

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Executive Summary

TruePosition commissioned TechnoCom to perform indoor testing of its Hybrid UTDOA/AGPS location technology solution in a manner analogous to the tests recently performed by TechnoCom for CSRIC in the Bay Area. The indoor test campaign was performed in late February to early March 2013, in the Wilmington, Delaware area, where TruePosition has an existing deployment of its UTDOA network-based technology. The emphasis in planning and executing this indoor testing campaign was on maximizing the similarity with the testing performed in the Bay Area.

A test plan mirroring the CSRIC indoor test plan was developed by TechnoCom. The Wilmington area was examined to determine the applicable test environments (morphologies). It was determined that both the urban and suburban morphologies were prevalent. (Downtown Wilmington was deemed too small to offer a realistic dense urban setting and the rural areas near Wilmington had a cell site density higher than what was tested in the rural area of the indoor test bed in California., hence, both were not included among the morphology definitions to preserve the integrity of the analogy).

TechnoCom defined an urban and a suburban polygon providing a wide spectrum of test scenarios. TechnoCom then proceeded to identify candidate buildings per the requirements of the test plan. Again, as was experienced in the CSRIC test bed, identifying and securing access to the buildings for indoor testing was a particularly challenging and time consuming step in the project.

46 test points were selected by TechnoCom in 10 buildings, 5 urban and 5 suburban. The location and identity of the test buildings and test points were maintained anonymous to TruePosition until the delivery of this report.

To ensure that indoor ground truth accuracy did not introduce measurable errors in the results, TechnoCom used a certified land surveyor. The certified survey accuracy was better than +/-5 cm, which is considerably better than the minimum required accuracy.

The results are provided for the location performance attributes under test, namely, location accuracy, yield, time to first fix (TTFF), and reported uncertainty, and location scatter. The summary results aggregated per morphology and per building are presented in the main body of this report and the more detailed per test point results are compiled in the appendix. Concise observations on the results, which benefit from the insight gained by TechnoCom in selecting the test points and becoming familiar with their surroundings, are also provided to aid the reader in interpreting the results.

The Hybrid UTDOA/AGPS system performed well indoors. Notably, very few outliers were observed, with well over 95% of test calls with errors below 200 m. In all cases the yield was extremely high, close to 100%.

It can be concluded that the addition of AGPS to UTDOA in the hybrid solution improved traditional performance overall, particularly in the suburban environment. Smaller buildings and buildings with many windows, whether in an urban or suburban setting, experienced good performance due to the combination of AGPS with UTDOA.

In TechnoCom's opinion the TruePosition system has undergone a rigorous indoor test similar to the CSRIC indoor testing performed in the Bay Area. To that extent, the results provided herein are representative and are provided to the FCC to include in its consideration of the information pertaining to the indoor performance of location systems applicable to E911.

1 Introduction

1.1 Background

The FCC commissioned its third Communication, Security, Reliability and Interoperability Council (CSRIC III), specifically its Working Group 3 (WG3), to advise it on critical and timely issues related to wireless E911. Critical among these has been the indoor performance of existing and emerging technologies applicable to E911. A very large number of US adults and children rely exclusively on wireless E911 to reach emergency services and this number continues to increase, making it a critically timely issue.

WG3 contained a very diverse and distinguished representation from all parties concerned with E911, including the wireless carriers, location technology vendors, 3rd party solution and service providers, and of course public safety. The consensus approach adopted by WG3 was to perform objective side-by-side testing of the available location technologies using a credible, independent third party to perform the testing. Due to the tight time limits on the CSRIC activity, testing had to be completed by mid-December 2012.

This very strict time constraint, coupled with various contractual complexities, made it infeasible for TruePosition to get its location system in the Bay Area ready for testing in the prescribed time frame. Instead, TruePosition recommended to CSRIC WG3 that it perform additional testing in the Wilmington, Delaware area, where the TruePosition location system could be made ready in a very short period of time. For various reasons, WG3 decided that such testing would not be possible within the CSRIC III timeframe.

Fully cognizant of the importance of indoor location performance in support of E911, and to provide the FCC with as much information as possible on indoor location accuracy and reliability, TruePosition decided to independently carry out an indoor testing campaign that is as similar and equivalent as possible to the indoor testing that was performed by CSRIC in the Bay Area.

This report presents a summary of this indoor testing effort in Wilmington and the associated indoor location performance results of TruePosition's Hybrid UTDOA/AGPS technology, which is a combination of two well established, widely deployed technologies.

1.2 Similarity to CSRIC Indoor Testing

To obtain location performance results that are analogous to those obtained for the technologies tested in the CRSIC test bed, a very similar test process was followed. One of the key principles of the CSRIC test bed was to provide the FCC with objectively derived, independently collected test results. Two fundamental aspects to ensure this is attained were: (1) the use of a credible, independent, and neutral test house to perform the testing, and (2) maintain test point anonymity, where the technology participants do not have an influence on where specifically or under what indoor conditions the tests are performed.

These basic principles were fully adopted by TruePosition. Moreover, to insure the maximum adherence to the details of the testing processes followed for CSRIC, the same independent test house was retained to perform the tests in Wilmington. Furthermore, the same test methodology in representative morphologies was adopted including the detailed aspects of testing, which mirrored the test process employed in the Bay Area. To the extent possible, the test environments chosen in the Wilmington area attempted to duplicate the indoor environments examined in the Bay Area. The test point selection followed similarly rigorous and demanding selection criteria mirroring the criteria used in the CSRIC indoor test bed.

1.3 Independent Test House

Since its inception in 1995, TechnoCom has been providing its engineering expertise to a host of location technology companies and wireless carriers evaluating and subsequently deploying some of those technologies. Throughout its history, TechnoCom has opted to take a location technology vendor independent approach to its E911 quality of service assurance and testing business.

Over the last decade, TechnoCom has also been a key player in the development and adoption of industry standard E911 testing methodologies. Notably, TechnoCom was a lead contributor in the development of the indoor testing methodology within ATIS's ESIF, which is the methodology that was adopted by CSRIC WG3 as the basis for indoor testing within its Bay Area test bed.

TechnoCom brought to the current Wilmington indoor tests its very recent, highly detailed experience performing the indoor testing and reporting for CSRIC WG3 and in turn to the FCC. TechnoCom has strived to duplicate, to the extent possible, the environments encountered in the Bay Area testing.

1.4 Scope of Report

This report contains the results of the indoor testing performed by TechnoCom on behalf of TruePosition in the Wilmington area in late February and early March 2013. To cast the results in the proper context and highlight the similarity with the CSRIC test bed in the San Francisco Bay Area, sections that concisely describe the methodology, scope of testing, test criteria, and test execution are provided. These are followed by descriptions of the representative environments (morphologies) in which the testing took place along with the specific buildings selected for inclusion in the Wilmington testing. This provides a reference framework to interpret the results which are subsequently presented. For the reader's convenience, the various results are provided in summary tabular and graphic forms. The results are first aggregated by morphology then presented aggregated per building within each of the two morphologies. This sheds light on the performance differences between distinct types of buildings within each broadly defined environment. For the interested reader, more detailed results for each of the 46 test points are provided in an appendix attached to this document. Concise observations and conclusions based on the various results are also included in this report to aid the reader in interpreting the results.

1.5 Contact Information

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2 Test Approach

2.1 Representative Morphologies (Use Environments)

As mentioned in the Introduction, the Wilmington indoor testing for TruePosition followed the same methodology used for CSRIC in the San Francisco Bay Area. This included the same morphology to test point logical flow down as shown in Figure 2.2-1.

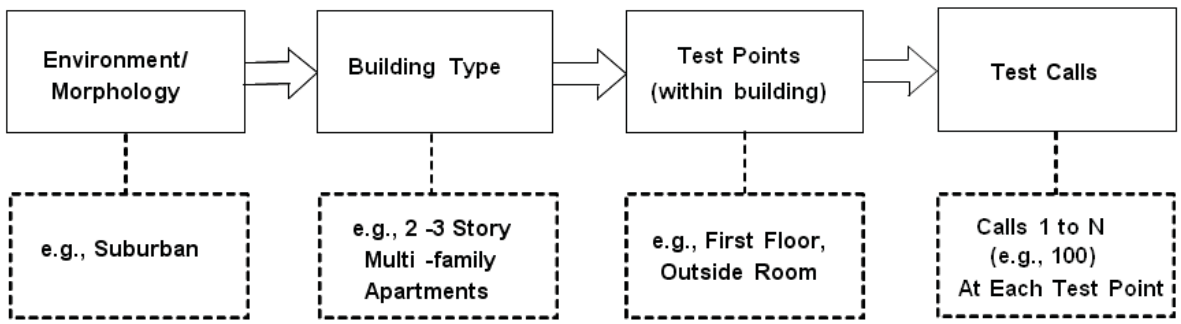

Figure 2.1-1. Morphology, Building and Test Point Flow Down

In each morphology (i.e., broad wireless use environment) a number of buildings of different sizes and types common in that morphology were identified. Within each building different test points were selected to represent the range of conditions encountered within that building.

In contrast to the greater Bay Area where representative polygons were identified for all four basic morphologies, namely, dense urban, urban, suburban, and rural, only urban and suburban polygons were suitable for identification in the Wilmington area. This will be described below in Section 5 presenting the detailed test environments

The number of test points in each building depended on its size and complexity and ranged from 2 to 6 similar to CSRIC testing. At each test point a statistically significant number of independent test calls (at least 100) was placed from the test handsets. (Details on that will be provided below in Section 3).

In aggregate, 10 buildings spanning the two distinct morphologies (urban and suburban) and a good spectrum of building types, construction materials, and settings were attained. This was complemented by a sizeable number of test points (46) over a wide range of indoor test scenarios inside those buildings. This created a broadly representative sample of indoor performance in those critical urban and suburban environments, which are the most populated environments in the United States.

2.2 Anonymous Test Buildings and Test Points

TechnoCom independently performed the tasks of test building identification and test point selection. At no time until the delivery of the report did TruePosition know the test buildings, the indoor test scenarios chosen or the ground truths of the test points. TruePosition, however, did have access to daily logs of location system obtained fixes, which it forwarded to TechnoCom on a daily basis. This is a process identical to that adopted in the CSRIC indoor testing in the Bay Area.

2.3 Statistically Significant Samples

Indoor location performance can suffer from rapid changes in signal conditions and can experience significant performance variation from call to call even within a short period of time. It is therefore necessary to use a large enough sample of independent calls at each test point to arrive at reliable (statistically significant) performance statistics. The consensus adopted by WG3 for the CSRIC testing was a minimum sample size of 100 test calls per technology per test point. The same was required and attained in Wilmington at every test point.

2.4 Accurate, Reliable Indoor Ground Truths

The general requirements for indoor ground truth accuracy were quoted in ATIS-0500013. However, the CSRIC test bed was a particularly visible benchmark in which TechnoCom deemed it important to follow the most exacting of ground truth determination methods described in 0500013, namely using a professional survey company. The same exacting approach was elected by TechnoCom for the Wilmington indoor testing. A local certified land surveying vendor from the Wilmington Area was contracted to perform precise ground truth surveys for the test point selected by TechnoCom's senior engineers. This ensured that highest quality and reliability in comparing the test call results to the actual ground truths of the selected test points.

The survey information provided by the vendor included latitude, longitude and height. The certified accuracy is +/-5 cm in the horizontal or vertical directions, which is much better than the minimum needed for indoor wireless E911 applications. The survey method and equipment are described in Section 4.2, along with a sample survey ground truth output measurement.

2.5 Performance Attributes Analyzed

2.5.1 Location Accuracy

The error in estimating the location of the TruePosition device under test was computed by comparing its reported horizontal position (provided to TechnoCom) to the surveyed ground truth position of the test location (determined through the precise survey). Each test call was assumed to be independent from prior calls and accuracy was based on the first location delivered by the TruePosition system after call initiation. (This applies specifically to UTDOA; AGPS locations used in the hybrid solution were computed in real time but obtained off line and provided to TechnoCom with the UTDOA logs).

This accuracy information is presented in Section 6 where the results are aggregated by building and morphology. In Section 7 more detailed results are presented for each building within the two morphologies. The accuracy statistics include the 67^{th}, 90^{th} and 95^{th} percentiles of horizontal accuracy, standard deviation of error, and minimum and maximum errors, all in meters. In addition, the error CDF has also been provided for each technology aggregated by morphology in Section 6 and for each building in Section 7. More detailed accuracy results for each of the 46 test points are provided in the appendix.

2.5.2 Latency (TTFF)

The Time to First Fix (TTFF) or the time to obtain the first computed caller location is reported only for the UTDOA portion of the Hybrid technology. These results are aggregated by building and by morphology. (Per point results are also provided in the appendix.) This processing time is calculated by establishing the time from test call initiation to the delivery of the UTDOA component of the fix. Since the AGPS component of the fixes that entered in the UTDOA/AGPS Hybrid solution were obtained off line, it was not possible to present the TTFF for the Hybrid solution as a whole.

2.5.3 Yield

Yield is the % of calls with delivered location to overall "call attempts" at each test point. The yield statistics are for UTDOA based on the information received in the TruePosition test logs including the number of calls attempted by the test handsets. The summary yield results are reported in Sections 6 and 7 with the per test point results detailed in the appendix.

2.5.4 Reported Uncertainty

The uncertainty reported by the location system for the UTDOA/AGPS hybrid is also presented. The reported uncertainty at each test point (corresponding to a nominal 90% confidence) is compared to the fraction of calls for which the resulting (empirically measured) location falls inside the uncertainty circle. The ideal number would be 90% of the calls have an actual error that causes the reported locations to fall inside the reported uncertainty circle. In general, the quality of the uncertainty measure reflects how well a location system is operating, with poor performance often (but not always) associated with a low proportion of computed locations falling inside the reported uncertainty circle. The uncertainty results have been aggregated by building and by morphology with the detailed per point results provided in the appendix.

2.5.5 Location Scatter

To provide the reader with added insight into the qualitative indoor performance of the hybrid location technology under test in the different environments, to aid in discerning possible effects of specific structural features at certain test points, and to place observed error distances in the proper indoor perspective, scatter diagrams have been prepared and provided for each building in Section 7. As with the detailed results that were provided to CSRIC WG3, the location scatter results overlaid on the building landscape, e.g., from Google Earth imagery, yields considerable insight into the potential and limitations of the attained indoor performance in each setting. The resulting clusters for all the test points in the given building are shown in the scatter diagram for that building.

3 TruePosition Location Technologies Tested

The hybrid technology solution tested contained two components Uplink Time Difference of Arrival (UTDOA) and AGPS. The Hybrid solution was based on a weighted combination of UTDOA and GPS, with weights inversely proportional to their respective uncertainties.

3.1 UTDOA/AGPS Hybrid

U-TDOA is the widely deployed network-based multilateration solution from TruePosition. UTDOA determines location based on the time it takes a signal to travel from a mobile phone to a number of sensitive, well calibrated receivers called Location Measurement Units (LMUs). These are often placed at cell sites for logistical and engineering convenience. The UTDOA component included in the Wilmington was the same as that deployed widely in several large wireless carrier networks, such as those of AT&T and T-Mobile.

The hybrid solution is generated from a weighted average of the individual latitudes and longitudes returned by the AGPS and UTDOA solutions. It can be described as

Hybrid Latitude = WAGPS * AGPS Latitude + WUTDOA * UTDOA Latitude

Hybrid Longitude = WAGPS * AGPS Longitude + WUTDOA * UTDOA Longitude

where the weights (WAGPS and WUTDOA) are proportional to the inverse of the uncertainty value returned for each method.

If one of the two component methods fails, the weight for that method is set to 0.

One distinction between this Hybrid method and others that might be possible is that the UTDOA and AGPS are operating independently, i.e., individual UTDOA range measurements are not mixed with individual GPS pseudorange measurements. Other flavors of hybrid by TruePosition, such as a selection hybrid (chose UTDOA or AGPS) are possible, but are not presented here for simplicity and clarity.

3.2 Devices Tested

Two handsets were used in testing the TruePosition Hybrid solution as follows:

1. GSM Handset (2G)

   The GSM handset was a Motorola RAZR V3i containing a special PSAP simulator SIM (to ensure that test calls receive emergency call treatment on the AT&T network but are not routed to an actual PSAP)

2. UMTS Handset (3G)

   Although UMTS (3G) positioning was not tested in the Wilmington indoor tests, the 3G handset was used to provide the GPS related information in support of the 2G UTDOA/AGPS Hybrid solution. The UMTS handset was an LG Phoenix, which contained a Qualcomm AGPS chipset. It was also equipped with a special PSAP simulator SIM.

2G RAZR 3G LG Phoenix

Figure 3.2-1. Handsets Used in the TruePosition Indoor Testing

One handset of each type was included in the test fixture (see Section 4.3 for a picture of the assembly).

3.3 Test Configuration and Architecture

The field testing utilized TruePosition's Drive Test Tool (DTT), which is a combination of hardware and software used to place test calls in a cellular network that can be located by a location positioning system

- The DTT is comprised of a client called the Drive Test Client (DTC) that resides on a laptop connected to the handsets under test and a server component referred to as the Drive Test Server (DTS) within the TruePosition network
- The DTC collects call data and transmits/receives to and from the DTS. The DTC is composed of the following elements:
    - Windows Laptop Computer
    - TruePosition DTC Software
    - Cell Phone(s)
    - Data Connection Card w/ optional External Antenna
- The DTC provides a user interface to configure and originate test calls
- The DTT is mostly automated and requires little intervention after the test calls have begun

The elements for the TruePosition test system are illustrated in Figure 3.4-1. The test architecture is shown in Figure 3.4-2 The one system architectural feature to note here is that the AGPS component of the 2G hybrid UTDOA/AGPS solution was derived from a separate 3G (UMTS) handset placed on the same test platform as the 2G test handset (see Figure 4.3-1 for a picture).

TruePosition reports that it worked with the handset vendor of the DTT to ensure that the AGPS assistance data cache is cleared between subsequent location attempts, thereby ensuring the independence of repeated AGPS and Hybrid fixes.

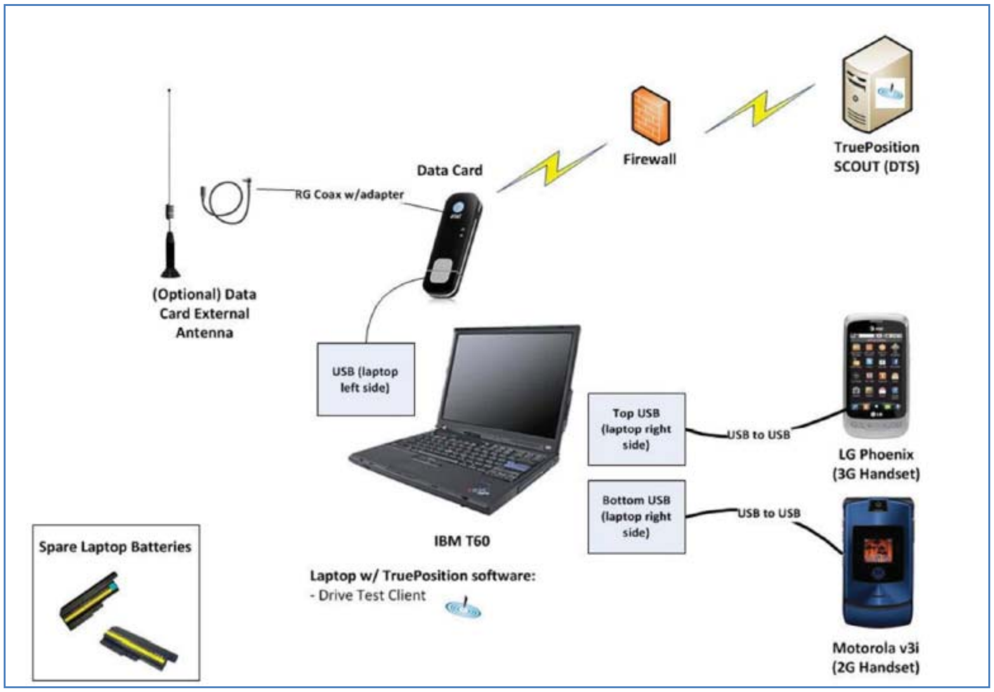

Figure 3.3-1. TruePosition Test System Elements for Wilmington

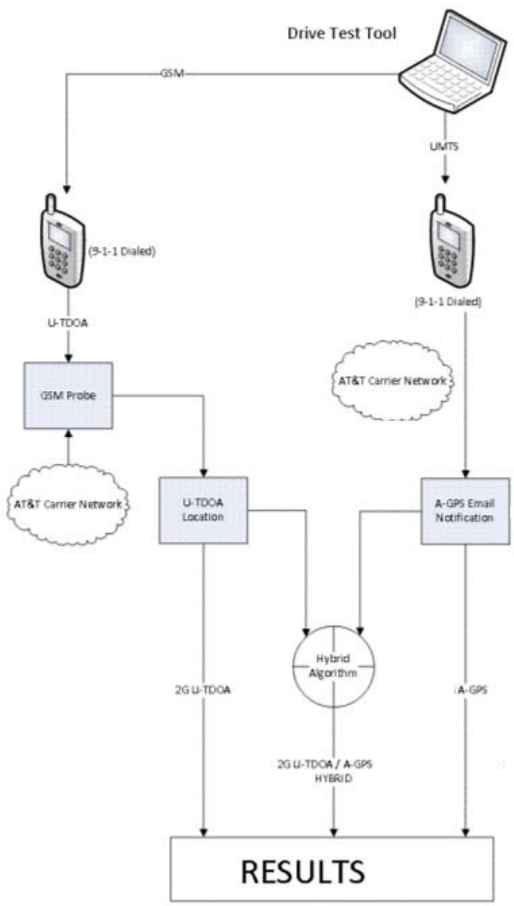

Figure 3.3-2. TruePosition's Test Architecture for the Hybrid Solution

4 Test Execution

4.1 Test Point Selection

TechnoCom's principal engineers/location experts evaluated possible candidate building selections and contacted their management. A letter of support from local public safety assisted in facilitating the communication with the building management. The evaluation of the possible buildings was in the context of the requirements of a test plan that mirrored the test plan that was adopted for the CSRIC testing. Buildings were evaluated for their fit into the criteria of selection for each morphology, including their location, their type of construction, their broad RF characteristics, their distinction from other buildings previously selected, and their physical and logistical access.

Upon granting of permission for access/testing, TechnoCom's principal engineer performed a walkthrough of each of the identified buildings to determine the appropriate test points. The test points were selected to meet the general requirements of the test plan with adequate diversity in their RF environment (including adequate cellular signal coverage), placement of the point in the building, and non-intrusive test performance. The test points were then documented and pictures taken to ensure that the ground truth survey team surveyed the specific points intended. At some buildings, access restrictions implied that the walkthrough, the formal survey, and the actual testing were all coordinated and performed on the same day.

In all, 46 points were selected broken down as shown in Table 4.1-1. More test points were selected in the urban area since its buildings were on average larger than some of the suburban buildings, which needed fewer test points to capture its representative scenarios.

Table 4.1-1 Summary of Test Point Distribution

Morphology	Number of Test buildings	Number of Test Points
Urban	5	26
Suburban	5	20
	Total	46

The identities and specific locations of all the test buildings and test points were maintained strictly anonymous to TruePosition until the delivery of this report.

4.2 Ground Truth Determination

A professional land survey company with experience in indoor surveying and local knowledge was selected by TechnoCom to perform the precise ground truth surveys. The surveyor used established land survey techniques using modern technology. The equipment used of the survey inside the buildings is shown in Figure 4.2-1. The following is a quote from one of the 10 formal survey reports prepared by the land surveyor.

"Surveyed positions were established using Leica GS15 SmartRover utilizing the Leica SmartNet CORS Network. These positions were established on Delaware State Plane Coordinate System in the NAD83 (NA2011) Reference Frame, Epoch 2010.0000 and converted to WGS84 Latitude and Longitude. Elevations were established in NAVD88 datum with the Geoid 09 Model. GPS control points were established outside the building with a horizontal and vertical positional tolerance of +/- 2 cm and traversing into the building was accomplished with a Leica TS15 Total Station resulting in a positional tolerance of +/- 5 cm in the horizontal and vertical."

Figure 4.2-1. Setup Used by Professional Surveyor for Ground Truth Determination

A sample surveyed location took the form:

Building X. Test Point: 1

Description: First Floor, interior office

Latitude: N39°43'XX.85581"

Longitude: W75°40'XX.84057"

Elevation: 91.96ft (28.03m) (NAVD 88)

WGS84 Ellipsoid Height: -16.06ft (-4.90m)

Although the test points were surveyed with exceptional accuracy and precision, a practical accuracy in test device placement relative to surveyed location was better than half a meter. The contribution of such placement tolerance to overall location error is completely negligible.

4.3 Test Fixture

For ease of transportation the test devices were mounted on a portable platform. As shown in Figure 4.3-1 the platform carried the laptop used in triggering the test calls and the two test handsets, placed each in a cradle atop a 12-inch arm. The two test devices were separated by approximately 18 inches.

Figure 4.3-1. Test Fixture Used During the Indoor Testing in Wilmington

4.4 Placement and Timing of Test Calls

The TruePosition drive test tool client on the laptop was programmed to task the two handsets (one GSM and one UMTS) to simultaneously place 100 calls to 911. These calls received emergency call location treatment but did not get routed to an actual PSAP because of the special SIMs used. Each test call was set by design to be 30 seconds long with a pause of 15 seconds between test calls. This resulted in approximately 75 minutes of test call placement duration at each test point. The AGPS result delivered to the drive test server from a 3G test call in that duration was subsequently time stamp matched to the corresponding UTDOA location fix of the 2G test call to generate the hybrid UTDOA/AGPS location fix.

5 Detailed Test Environments

5.1 Overall Test Area and Environment

TruePosition provided to TechnoCom geographical information on the areas in which its 2G and 3G test infrastructure is deployed. The area encompasses the City of Wilmington, DE and a wide swath of suburban areas extending towards the northeast, northwest and southwest. The general area is shown in Figure 5.1-1.

Although the area towards the northwest of Wilmington appears to be almost rural in density, the GSM site density in that area was not deemed sufficiently sparse by TechnoCom to consider as a truly rural environment. (Low site density was one of the key factors determining where the rural polygon was placed in the Bay Area CSRIC test bed.) Consequently, using a methodology similar to that used under CSRIC, the Wilmington test deployment area was considered to comprise only two morphologies: urban and suburban. (Downtown Wilmington is not sufficiently dense to qualify as dense urban.)

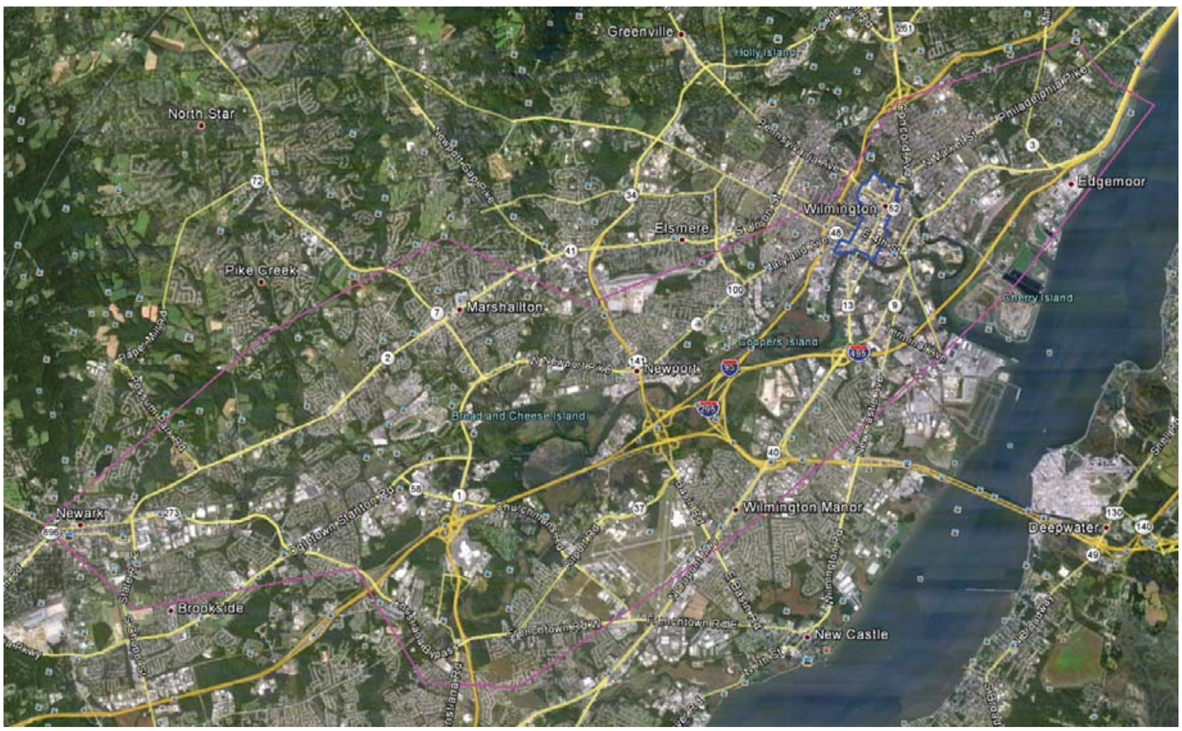

Figure 5.1-1. TruePosition's Wilmington Test Bed Area

5.2 Urban Morphology

5.2.1 Urban Polygon

The pink polygon shown in Figure 5.1-1 is a sizable area offering a wide variety of suburban scenarios and network characteristics; it was selected to serve as the suburban polygon for indoor testing. Within that large polygon, the urban morphology is concentrated in the City of Wilmington. TechnoCom defined, using techniques similar to what it had used for CSRIC in the Bay Area, a polygon that covers the urban morphology around downtown Wilmington. This polygon is shown in dark blue above and expanded in Figure 5.2-1 below. The blue-colored boundary follows similar definition and placement criteria (e.g., clutter type, building density, area layout) to what was followed in the Bay Area, for example surrounding Downtown San Jose. The area of the urban polygon was approximately 0.5 square mile, which is comparable to the size of the urban area that was used in San Jose by CSRIC.

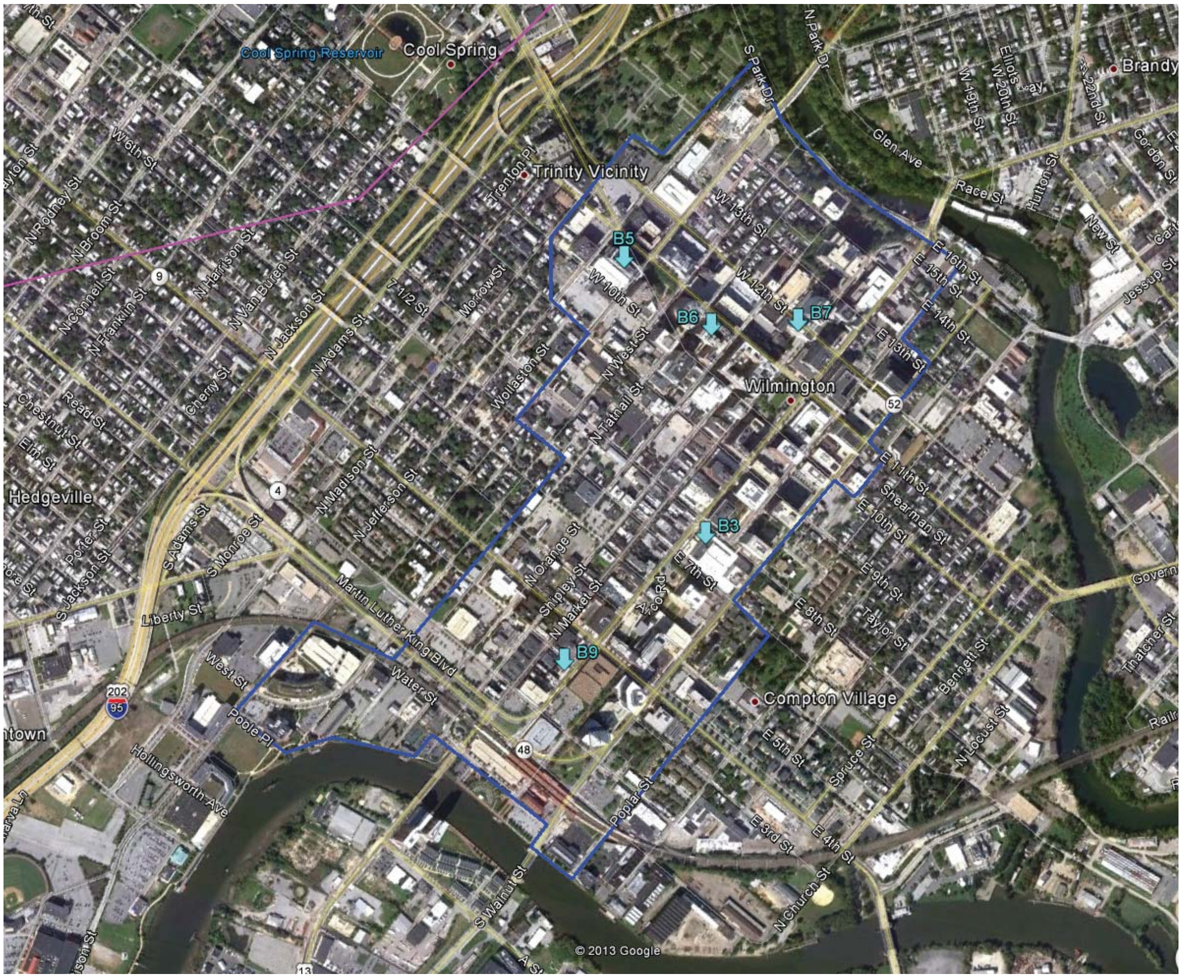

Figure 5.2-1. Urban Polygon and Relative Locations of the Urban Test Buildings

5.2.2 Urban Buildings Used

The urban buildings used for indoor testing in Wilmington are:

Bldg. 3: Double Tree Hotel, 700 N. King St., Wilmington, DE

Bldg. 5: 500 Delaware Ave., Wilmington, DE

Bldg. 6: Nemours Building, 1007 N. Orange St., Wilmington, DE

Bldg. 7: Wilmington Tower, 1105 N. Market St., Wilmington, DE

Bldg. 9: 233 King Street, Wilmington, DE

The geographic placement of the 5 urban test buildings is depicted in Figure 5.2-1. Both the denser area comprising central downtown Wilmington, with large and tall buildings, as well as the somewhat lighter urban part of the area, with buildings of varying heights, are included in the test sample. Different construction types are well represented, as can be clearly seen in the following figures, so are different propagation surroundings, e.g., differing surrounding building heights and the prevalence of dominant larger buildings to act as multipath reflectors.

Figure 5.2-2. Bldg. 3: Double Tree Hotel

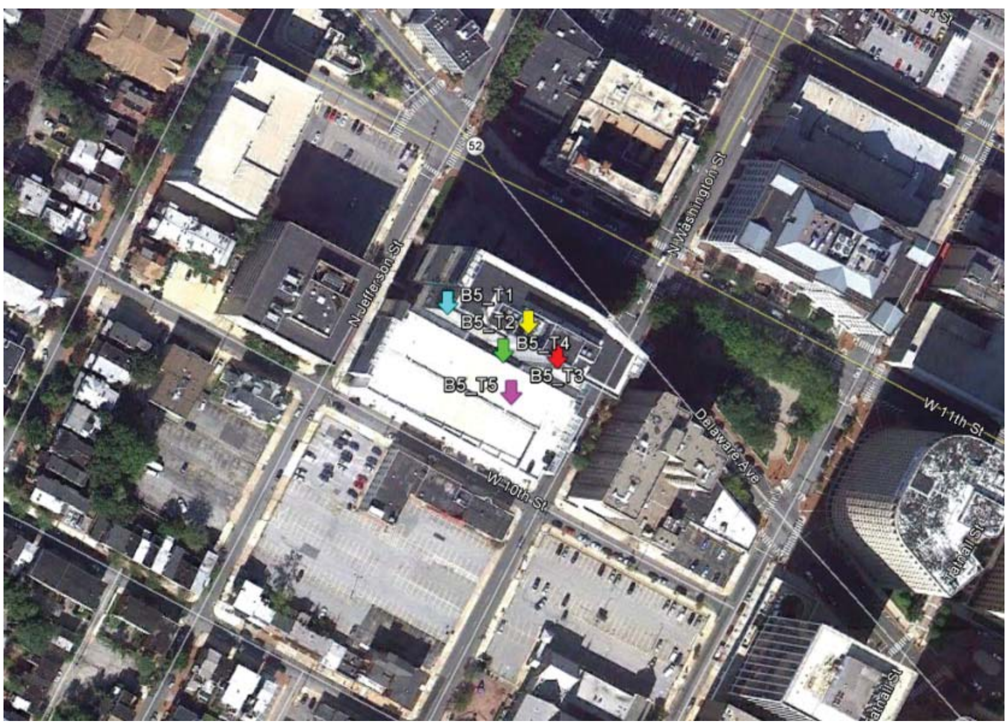

Figure 5.2-3. Bldg. 5: 500 Delaware

Figure 5.2-4. Bldg. 6: Nemours Building

Figure 5.2-5. Bldg. 7: Wilmington Tower

Figure 5.2-6. Bldg. 9: 233 King Street

5.3 Suburban Morphology

5.3.1 Suburban Polygon

The suburban polygon in the Wilmington area extends across a 15 mile swath, from northeast of downtown Wilmington to roughly 10 miles southwest of it. It encompasses an area of approximately 52 square miles, containing a wide variety of suburban densities, clutter types, building sizes and construction techniques.

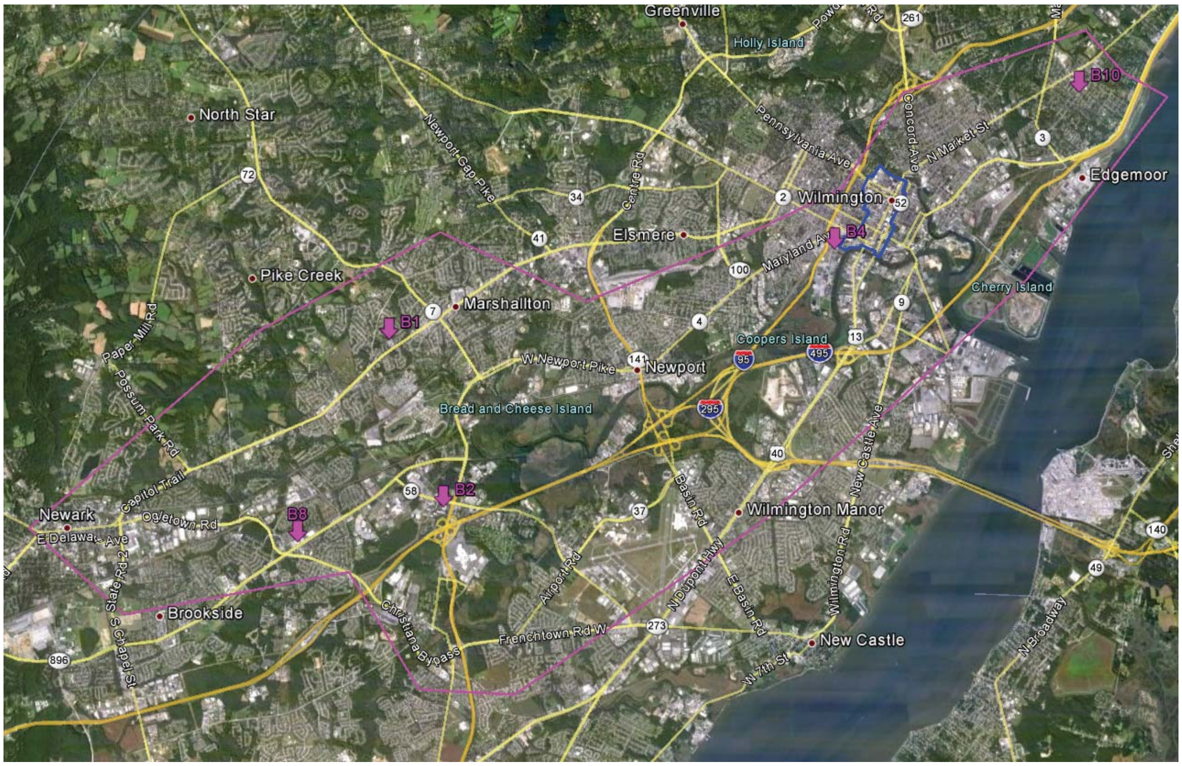

Figure 5.3-1. Suburban Polygon and Relative Locations of the Suburban Test Buildings

5.3.2 Suburban Buildings Used

The Suburban buildings used for indoor testing in the Wilmington area were:

Bldg. 1: 2-Story Townhouse, 5215 W. Woodmill Drive, Wilmington, DE.

Bldg. 2: Hilton Hotel, 100 Continental Drive in Newark, DE

Bldg. 4: Justison Landing (residential mid-rise), 331 Justison St., Wilmington, DE

Bldg. 8: “Iron Hill” Office Building, 700 Prides Crossings, Newark, DE

Bldg. 10: 2-Story Brick Building, 801 Brandywine, Wilmington, DE

These five buildings offered a wide spectrum of actual use environments in a diverse suburban area, ranging from a townhome, to a 3 story office building, to a hotel, to a relatively large mid-rise residential complex. Widely varying building sizes with distinct construction and different surrounding clutter were represented in this suburban building sample.

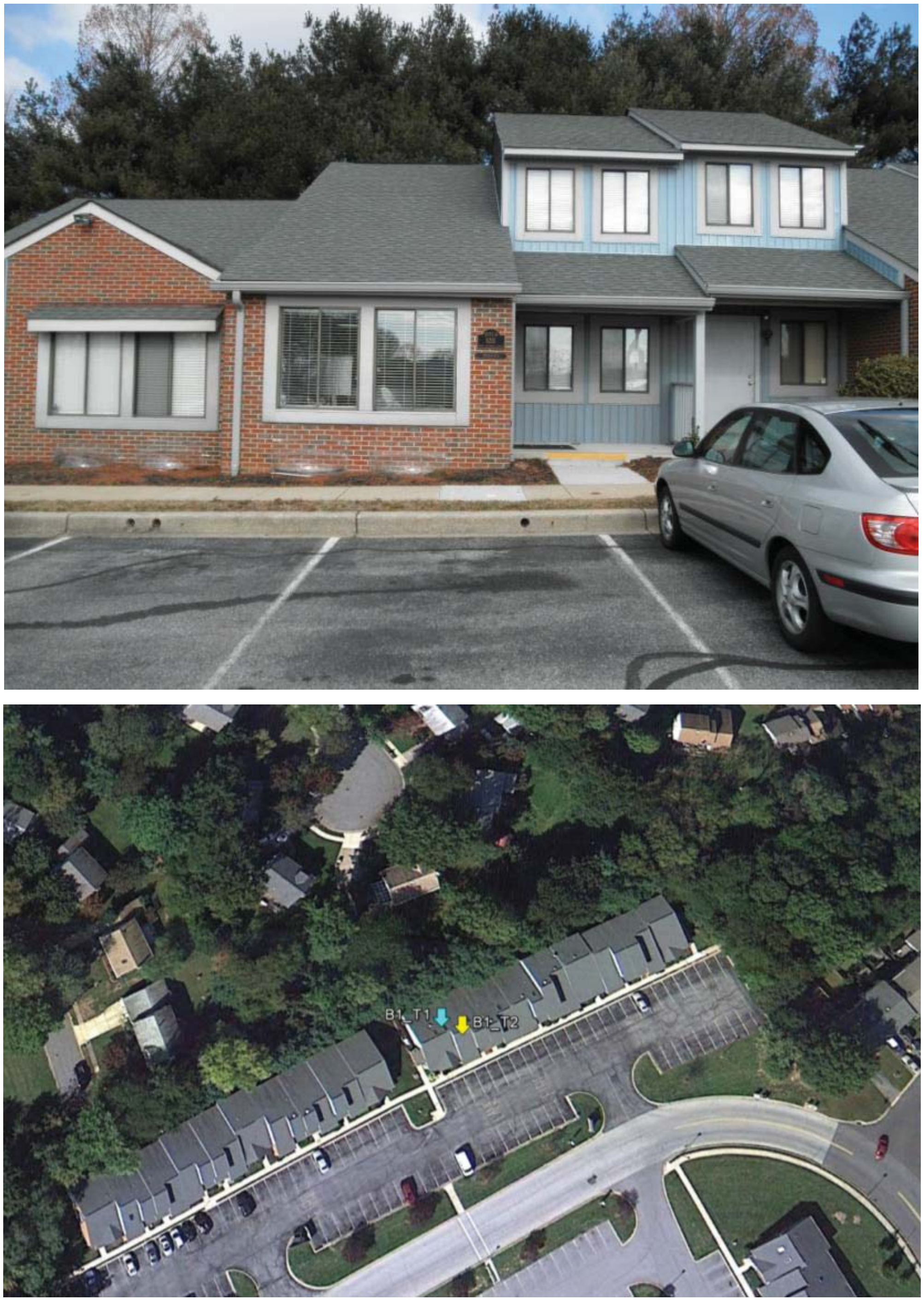

Figure 5.3-2. Bldg. 1: 2-Story Townhouse

Figure 5.3-3. Bldg. 2: Hilton Hotel

Figure 5.3-4. Bldg. 4. Justison Landing (Mid-rise Residential)

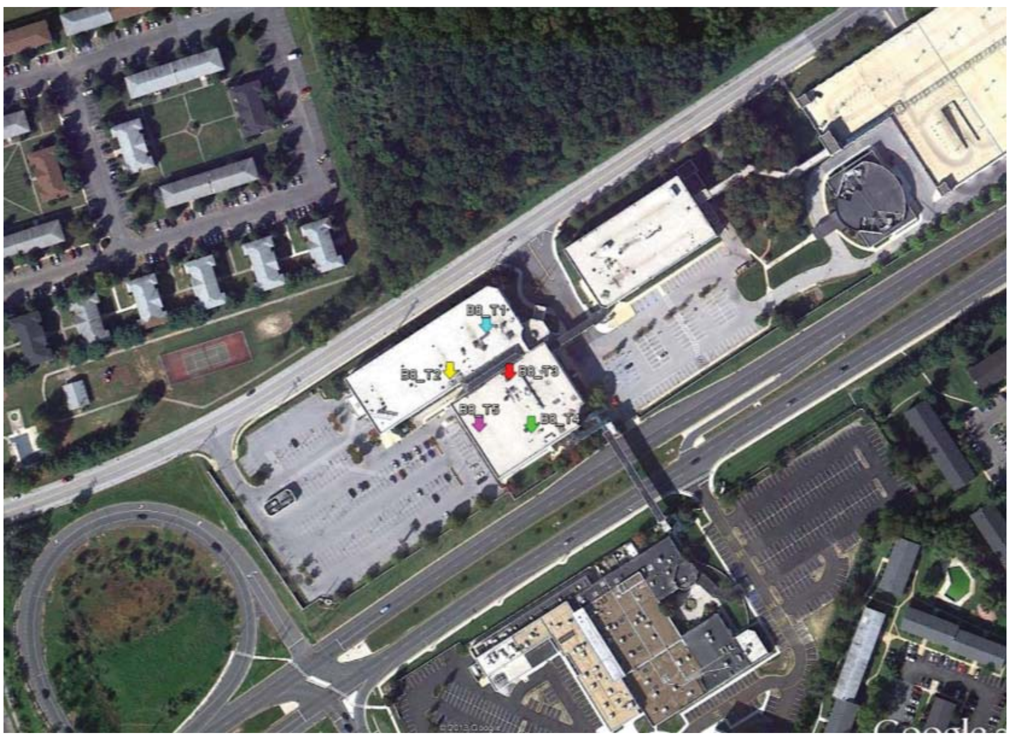

Figure 5.3-5. Bldg. 8: Iron Hill Office Building

Figure 5.3-6. Bldg. 10: 2-Story Brick Building

6 Summary Test Results

6.1 Number of Test Calls and Yield

The following two tables provide the summary yield results on a per building and per morphology basis. Table 6.1-1 provides the results for the urban buildings and morphology while Table 6.1-2 provides the results for the suburban morphology. As discussed above in Section 2.5.3, the yield is essentially that of UTDOA. (The AGPS locations used in the hybrid solution were computed in real time but obtained off line and provided to TechnoCom with the UTDOA logs.)

Table 6.1-1. Yield Results—Urban Environment

Number of Test Calls and Yield			
Building	Total Number of Test Calls Attempted	Total Number of Test Calls with Position Fix Received	Percentage of Test Calls with Fix Received (Yield)
TruePosition_BD3	509	509	100.0%
TruePosition_BD5	506	506	100.0%
TruePosition_BD6	610	610	100.0%
TruePosition_BD7	510	510	100.0%
TruePosition_BD9	509	509	100.0%
All Urban	2644	2644	100.0%

Table 6.1-2. Yield Results—Suburban Environment

Number of Test Calls and Yield			
Building	Total Number of Test Calls Attempted	Total Number of Test Calls with Position Fix Received	Percentage of Test Calls with Fix Received (Yield)
TruePosition_BD1	204	204	100.0%
TruePosition_BD2	519	519	100.0%
TruePosition_BD4	510	510	100.0%
TruePosition_BD8	509	509	100.0%
TruePosition_BD10	307	307	100.0%
All Suburban	2049	2049	100.0%

6.2 Accuracy Statistics

Table 6.2-1. Hybrid UTDOA/AGPS Indoor Accuracy Statistics—Urban Environment

UTDOA/AGPS Weighted Hybrid - Location Error Statistics (m)								
Building	Total Number of Calls	67th Percentile	90th Percentile	95th Percentile	Average Error	Standard Deviation	Max Error	Min Error
TruePosition_BD3	509	101.2	133.2	147.1	67.7	56.8	669.6	1.26
TruePosition_BD5	506	88.2	132.4	148.8	74.5	41.4	220.7	0.50
TruePosition_BD6	610	96.5	149.7	183.0	92.5	101.7	936.3	2.48
TruePosition_BD7	510	117.6	167.2	192.3	85.1	59.8	269.9	2.35
TruePosition_BD9	509	48.5	88.6	114.4	49.0	27.2	176.1	5.00
All Urban	2644	87.3	140.7	163.2	74.5	66.3	936.3	0.50

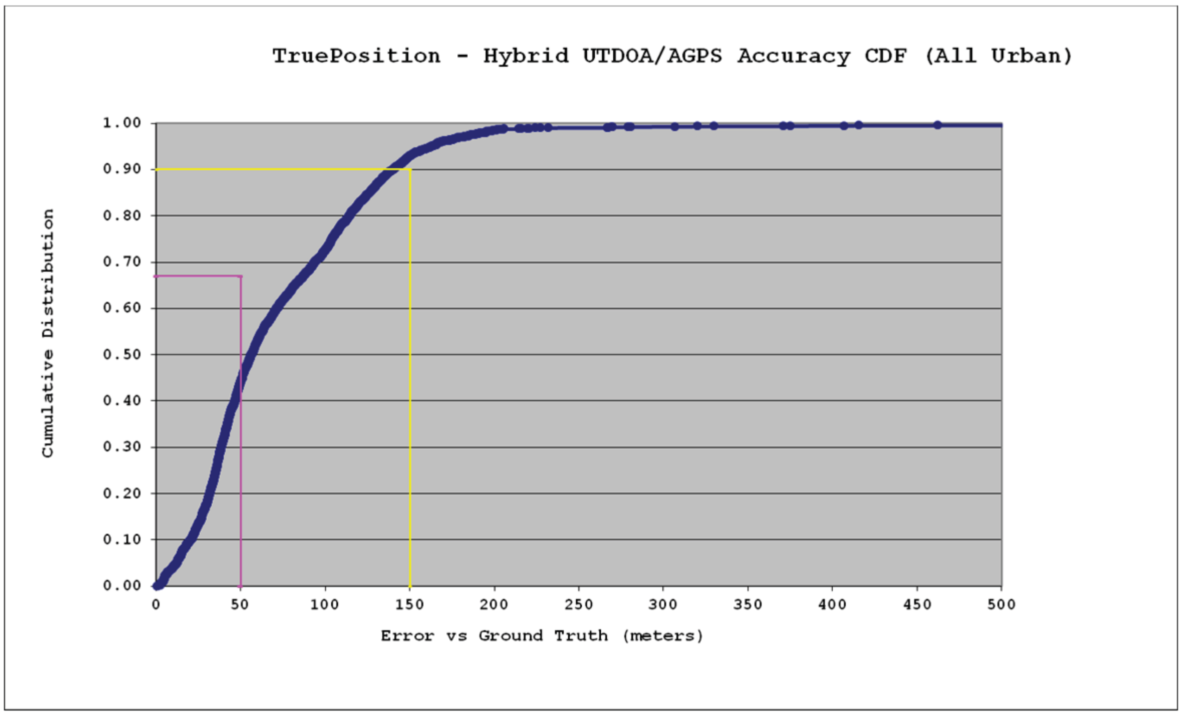

Figure 6.2-1 Hybrid UTDOA/AGPS Indoor Accuracy in the Urban Environment

Table 6.2-2. Hybrid UTDOA/AGPS Indoor Accuracy Statistics—Suburban Environment

UTDOA/AGPS Weighted Hybrid - Location Error Statistics (m)								
Building	Total Number of Calls	67th Percentile	90th Percentile	95th Percentile	Average Error	Standard Deviation	Max Error	Min Error
TruePosition_BD1	204	9.8	13.9	17.0	9.3	8.9	115.1	0.87
TruePosition_BD2	519	74.3	121.2	208.0	68.4	56.6	308.1	1.69
TruePosition_BD4	510	105.8	160.1	186.8	96.3	69.7	771.9	5.15
TruePosition_BD8	509	51.8	85.8	96.6	40.3	33.3	176.3	1.13
TruePosition_BD10	307	9.9	22.1	31.6	10.6	10.7	86.4	0.12
All Suburban	2049	66.1	116.2	155.7	53.8	57.8	771.9	0.12

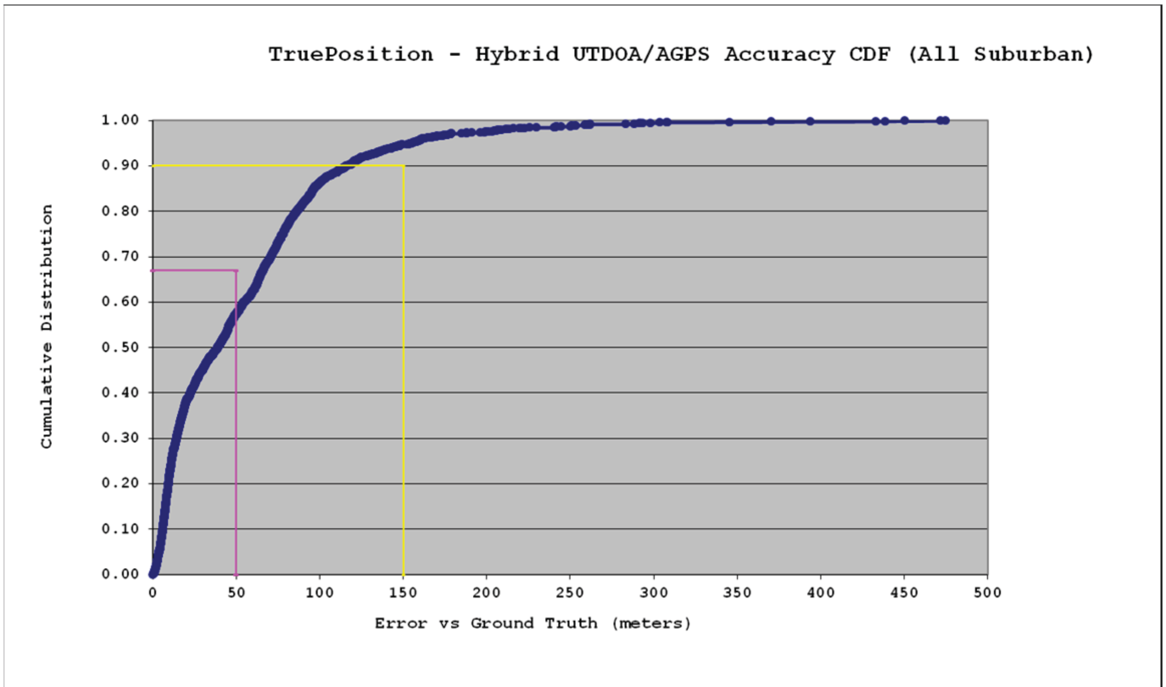

Figure 6.2-2 Hybrid UTDOA/AGPS Indoor Accuracy in the Suburban Environment

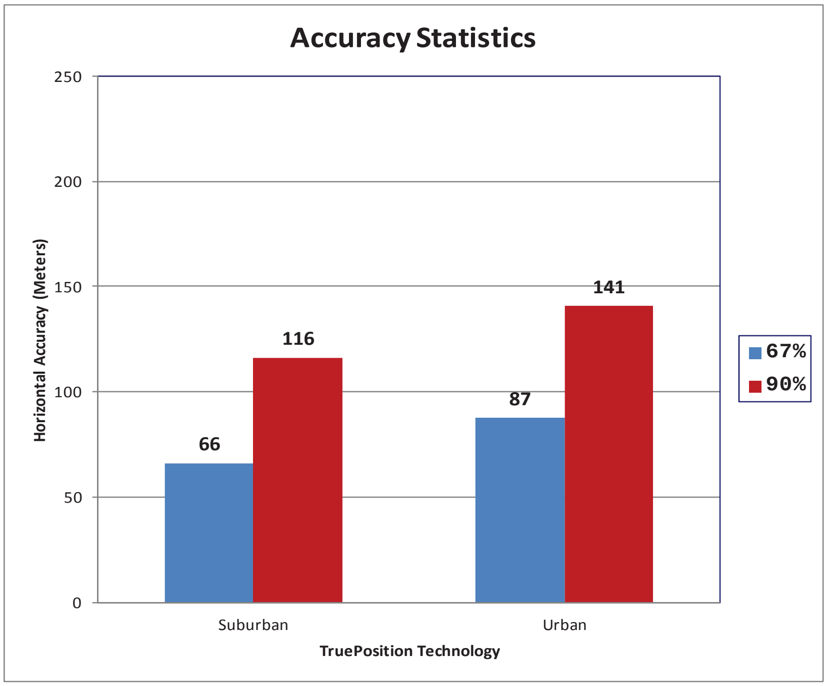

Figure 6.2-3 Hybrid UTDOA/AGPS Indoor Accuracy Percentile Summary

6.3 TTFF

The reported TTFF below was for the UTDOA portion only as the AGPS component was computed off line and there was not sufficient information to determine the TTFF of the entire Hybrid solution.

Table 6.3-1. TTFF for UTDOA—Urban Environment

UTDOA TTFF(Sec)				
Building	Average Duration	Standard Deviation	Max Duration	Min Duration
TruePosition_BD3	4.92	0.28	6.00	4.00
TruePosition_BD5	4.51	0.84	7.00	2.00
TruePosition_BD6	4.94	0.24	5.00	4.00
TruePosition_BD7	4.81	0.40	6.00	4.00
TruePosition_BD9	4.66	1.11	27.00	4.00
All Urban	4.77	0.68	27.00	2.00

Table 6.3-2. TTFF for UTDOA—Suburban Environment

UTDOA TTFF(Sec)				
Building	Average Duration	Standard Deviation	Max Duration	Min Duration
TruePosition_BD1	4.90	0.30	5.00	4.00
TruePosition_BD2	4.85	0.36	6.00	4.00
TruePosition_BD4	4.88	0.33	6.00	4.00
TruePosition_BD8	4.92	1.41	27.00	4.00
TruePosition_BD10	4.84	0.42	7.00	4.00
All Suburban	4.88	0.77	27.00	4.00

6.4 Reported Uncertainty

Table 6.4-1. Reported Uncertainty for Hybrid UTDOA/AGPS—Urban Environment

UTDOA/AGPS Weighted Hybrid Uncertainty			
Building	Total Test Calls	Number of calls with Error < Uncertainty	Percentage of calls Error < Uncertainty
TruePosition_BD3	509	309	60.71%
TruePosition_BD5	506	384	75.89%
TruePosition_BD6	610	368	60.33%
TruePosition_BD7	510	326	63.92%
TruePosition_BD9	509	163	32.02%
All Urban	2644	1550	58.62%

Table 6.4-2. Reported Uncertainty for Hybrid UTDOA/AGPS—Suburban Environment

UTDOA/AGPS Weighted Hybrid Uncertainty			
Building	Total Test Calls	Number of calls with Error < Uncertainty	Percentage of calls Error < Uncertainty
TruePosition_BD1	204	183	89.71%
TruePosition_BD2	519	293	56.45%
TruePosition_BD4	510	415	81.37%
TruePosition_BD8	509	375	73.67%
TruePosition_BD10	307	286	93.16%
All Suburban	2049	1552	75.74%

7 Summary Performance per Building

This summary provides insight into the performance of the Hybrid UTDOA/UMTS solution in different settings within the broad definitions of either the urban or suburban environments. For each building the cumulative CDF is presented together with the scatter diagram for that building. The scatter for each test point about the features pertaining to that building can be seen in these illustrations. A further level of detailed per test point performance, including an individual CDF for each test point, is provided in the Appendix.

7.1 Urban Buildings

7.1.1 Bldg. 3: Double Tree Hotel, Wilmington, DE

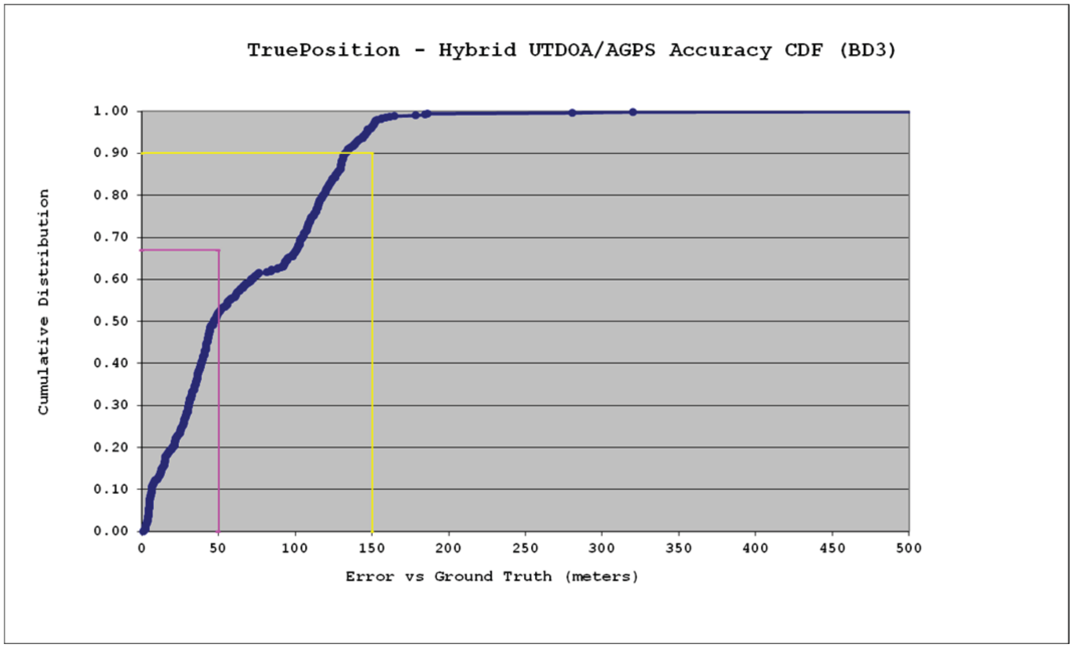

Figure 7.1-1. Bldg. 3 - Hybrid UTDOA/AGPS Accuracy CDF

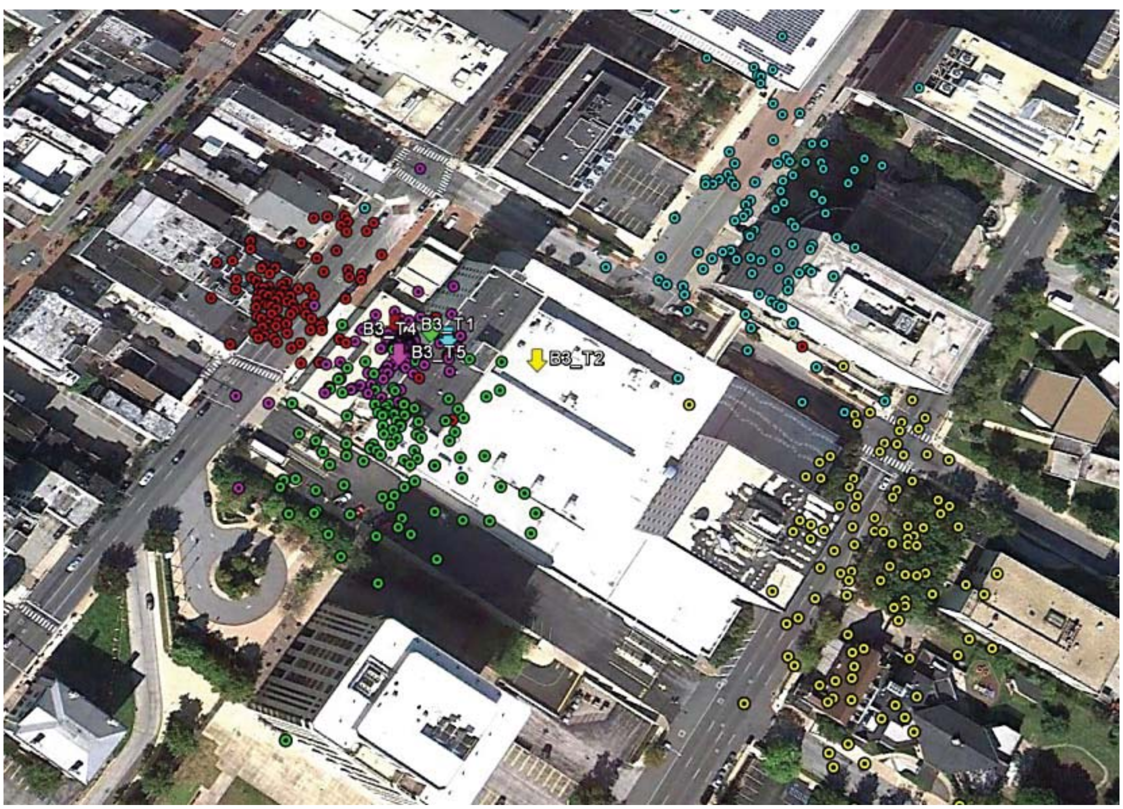

Figure 7.1-2. Bldg. 3 - Hybrid UTDOA/AGPS Location Scatter

7.1.2 Bldg. 5: 500 Delaware, Wilmington, DE

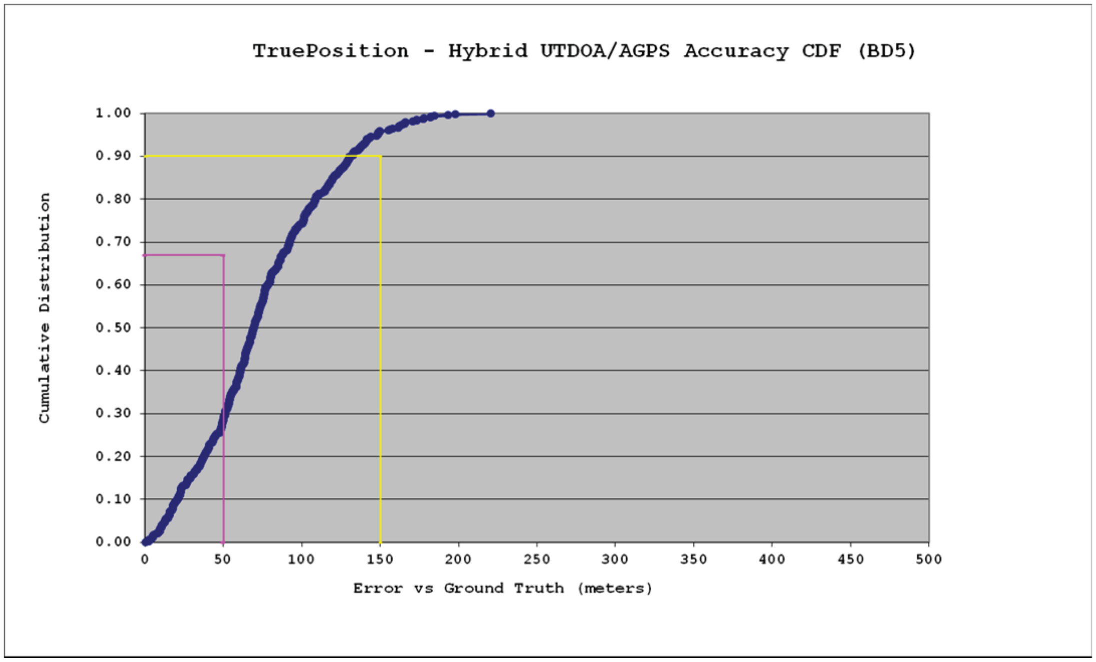

Figure 7.1-3. Bldg. 5 - Hybrid UTDOA/AGPS Accuracy CDF

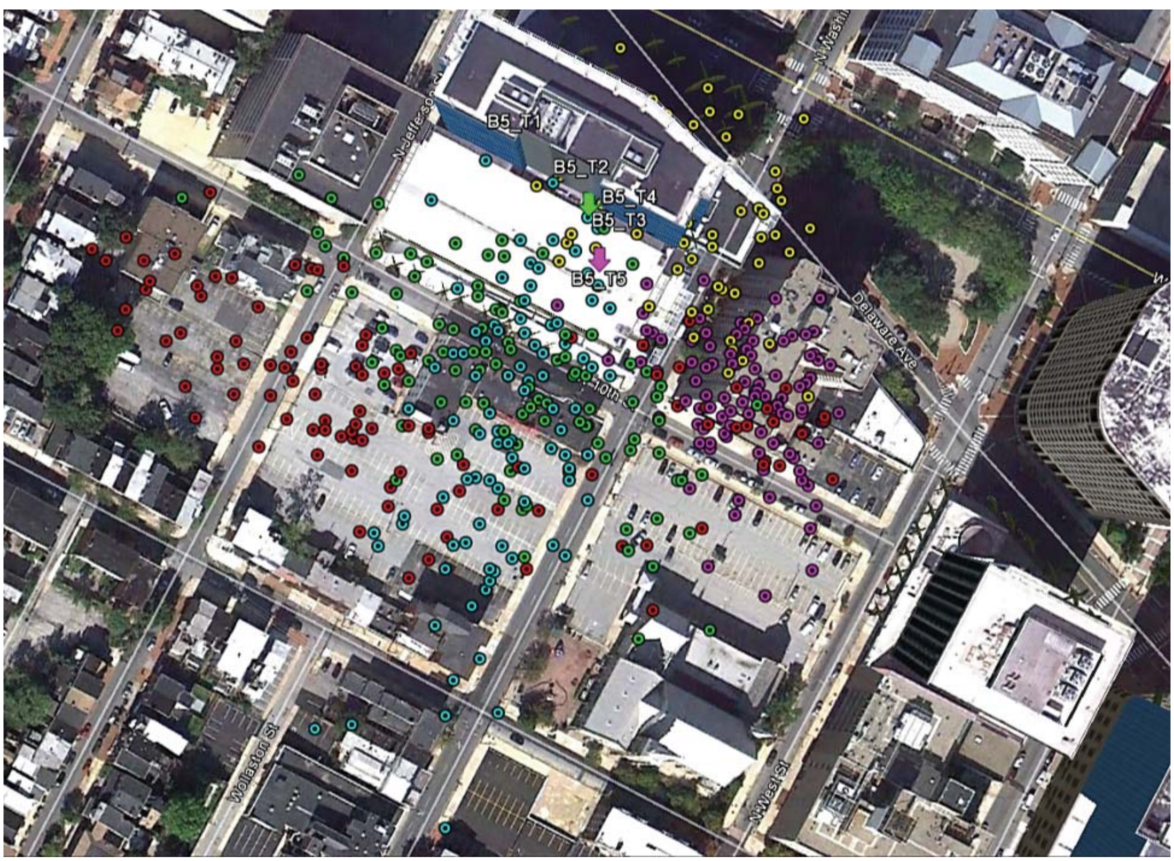

Figure 7.1-4. Bldg. 5 - Hybrid UTDOA/AGPS Location Scatter

7.1.3 Bldg. 6: Nemours Bldg., Wilmington, DE

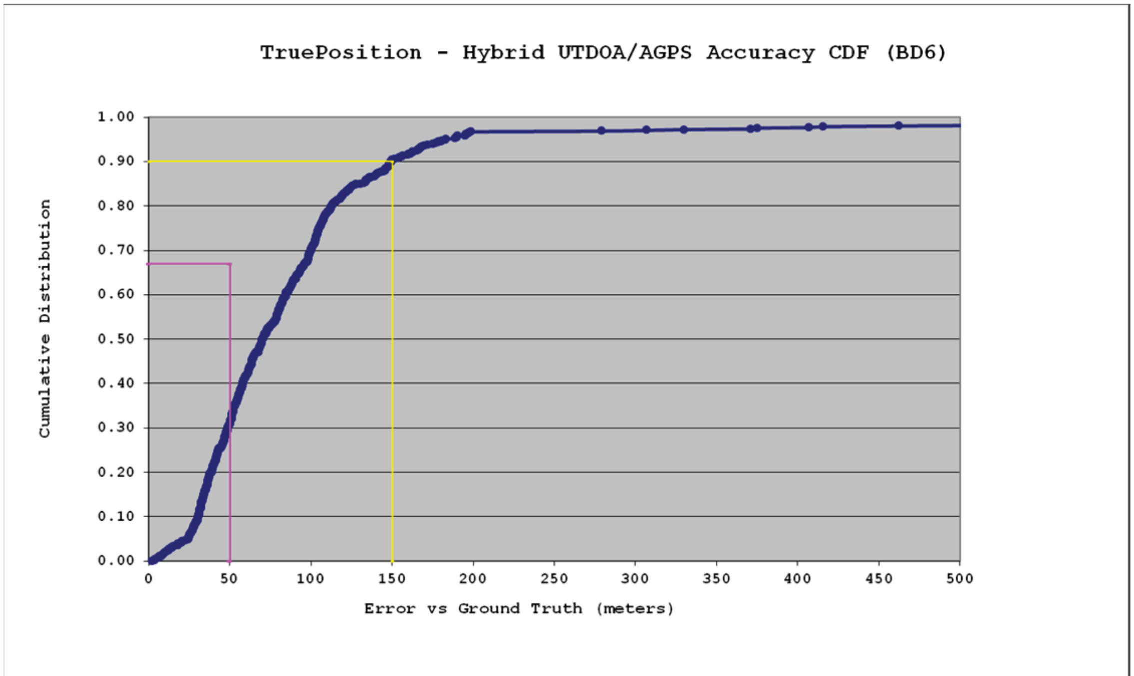

Figure 7.1-5. Bldg. 6 - Hybrid UTDOA/AGPS Accuracy CDF

Figure 7.1-6. Bldg. 6 - Hybrid UTDOA/AGPS Location Scatter

7.1.4 Bldg. 7: Wilmington Tower, Wilmington, DE

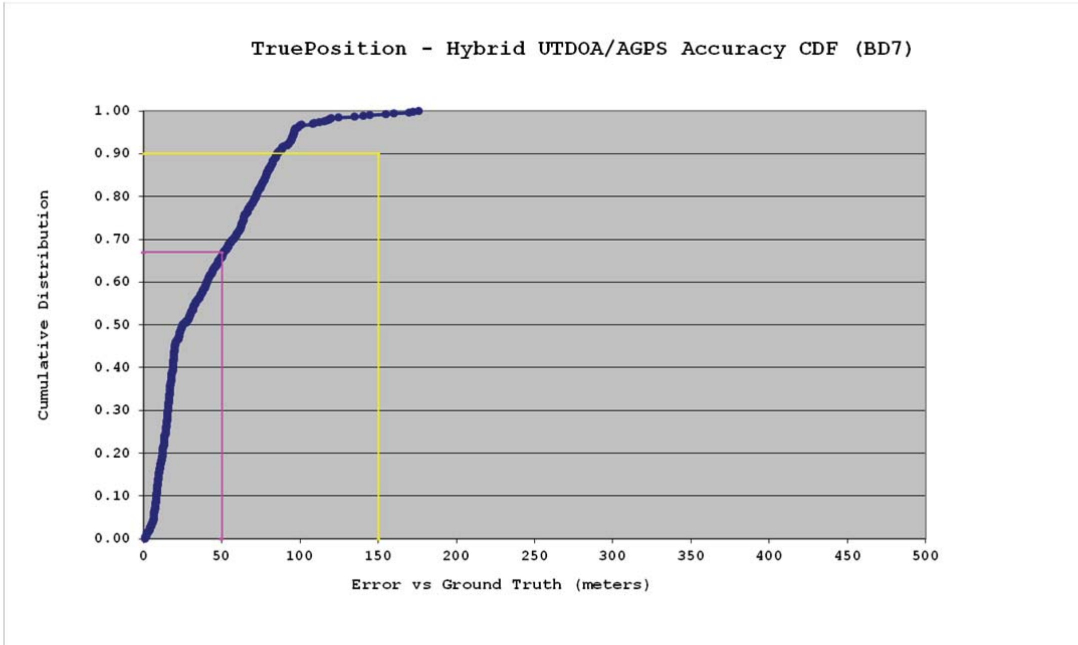

Figure 7.1-7. Bldg. 7 - Hybrid UTDOA/AGPS Accuracy CDF

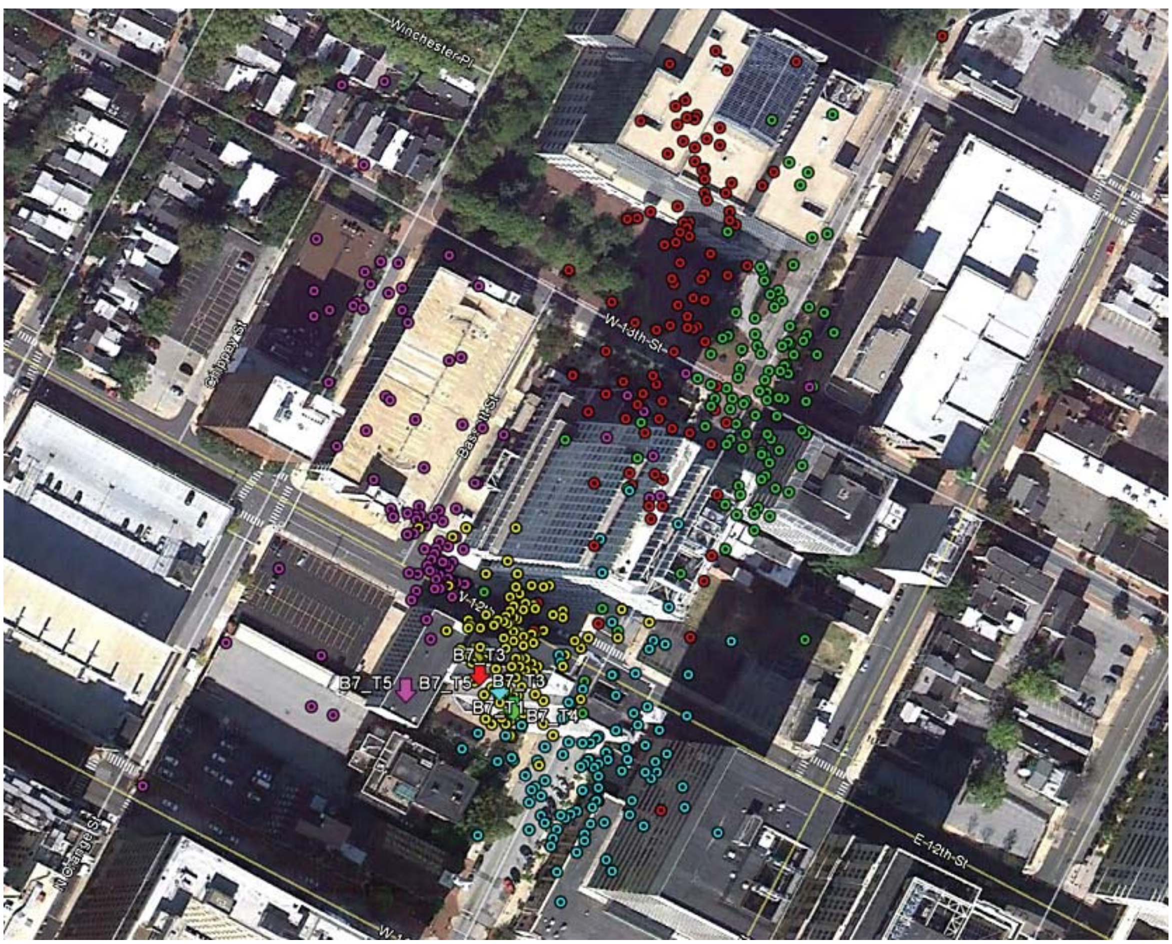

Figure 7.1-8. Bldg. 7 - Hybrid UTDOA/AGPS Location Scatter

7.1.5 Bldg. 9: 233 King Street, Wilmington, DE

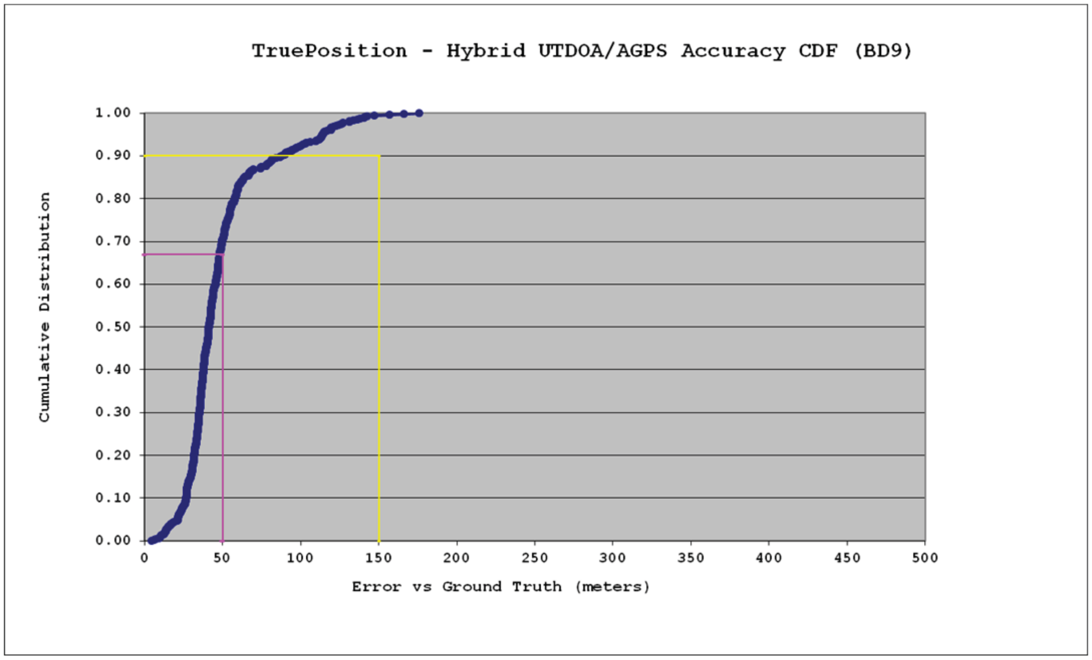

Figure 7.1-9. Bldg. 9 - Hybrid UTDOA/AGPS Accuracy CDF

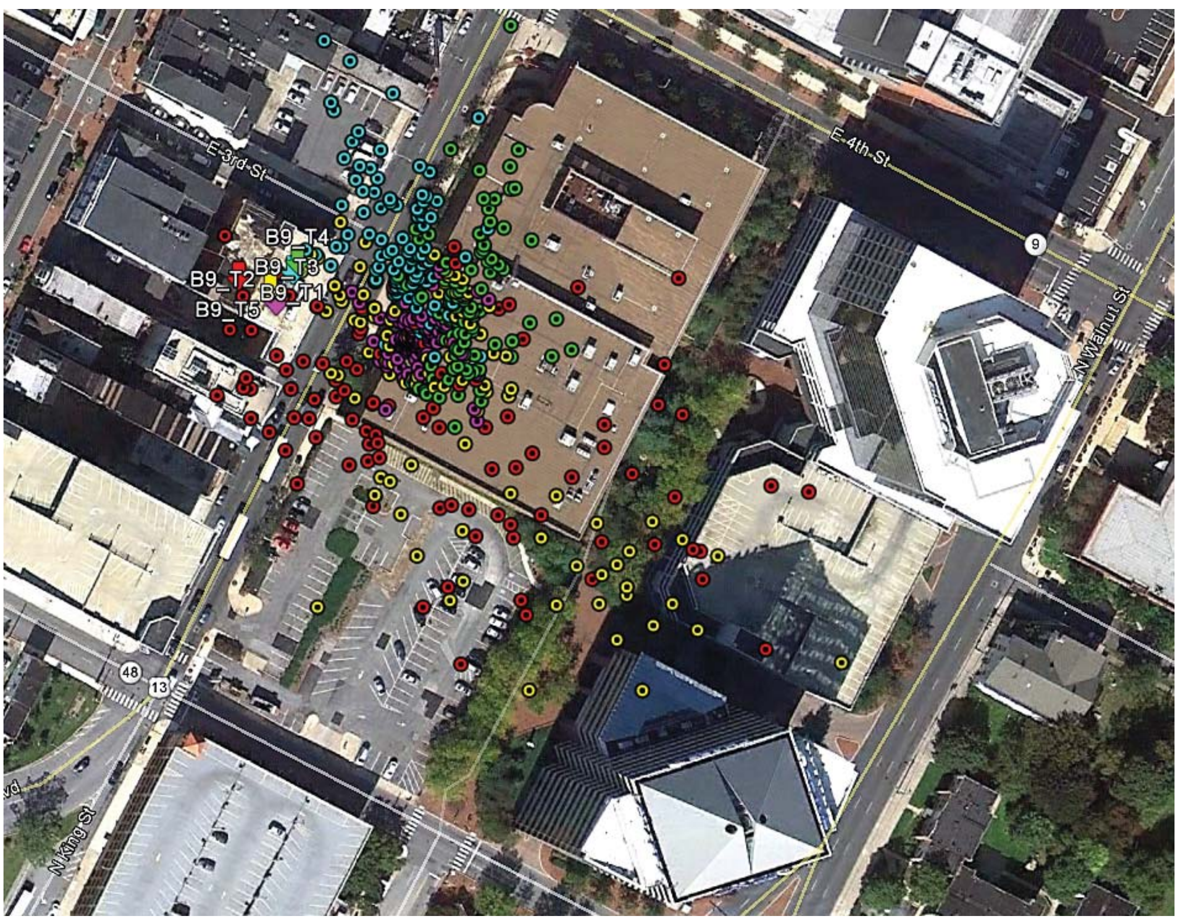

Figure 7.1-10. Bldg. 9 - Hybrid UTDOA/AGPS Location Scatter

7.2 Suburban Buildings

7.2.1 Bldg. 1: 2-Story Townhome, Woodmill Dr., Wilmington, DE

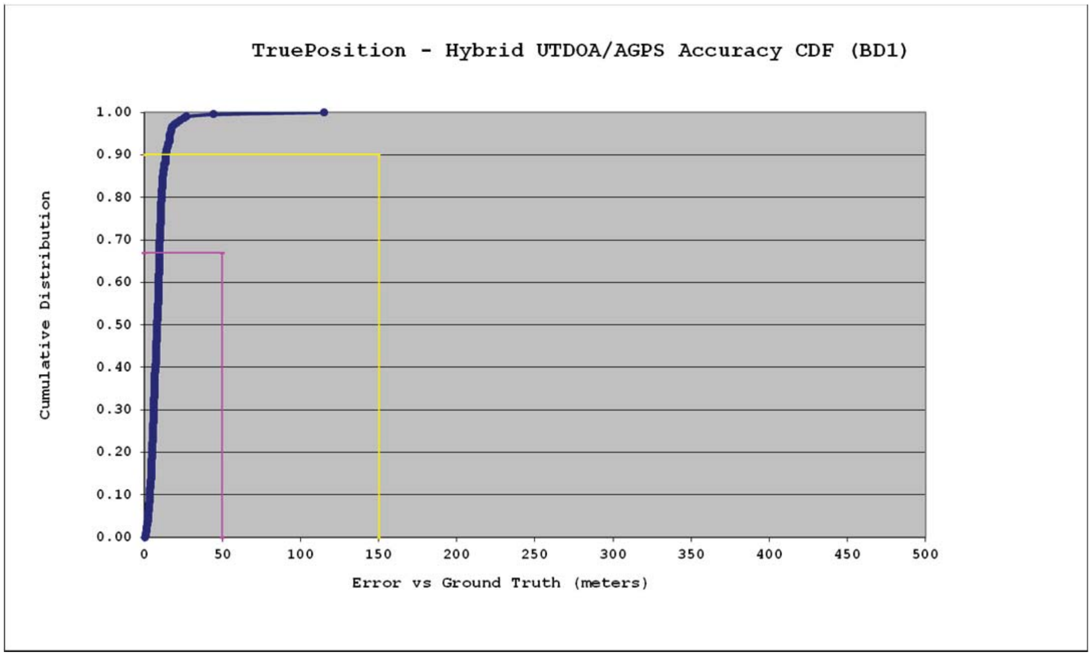

Figure 7.2-1. Bldg. 1 - Hybrid UTDOA/AGPS Accuracy CDF

Figure 7.2-2. Bldg. 1 - Hybrid UTDOA/AGPS Location Scatter

7.2.2 Bldg. 2: Hilton Hotel, Newark, DE

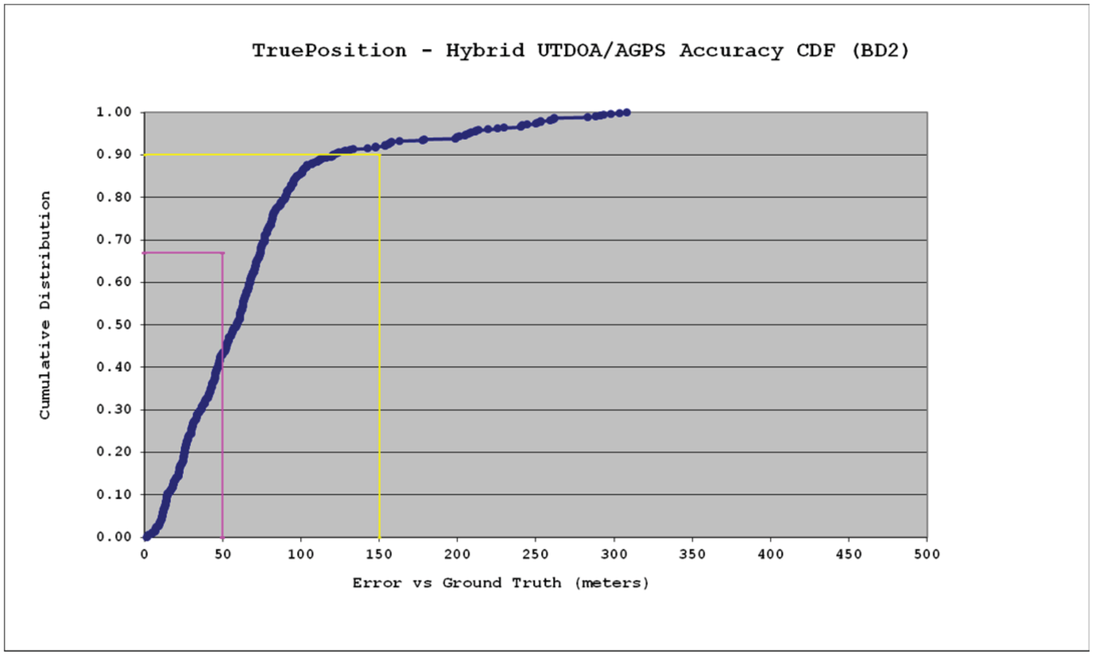

Figure 7.2-3. Bldg. 2 - Hybrid UTDOA/AGPS Accuracy CDF

Figure 7.2-4. Bldg. 2 - Hybrid UTDOA/AGPS Location Scatter

7.2.3 Bldg. 4: Justison Landing., Wilmington, DE

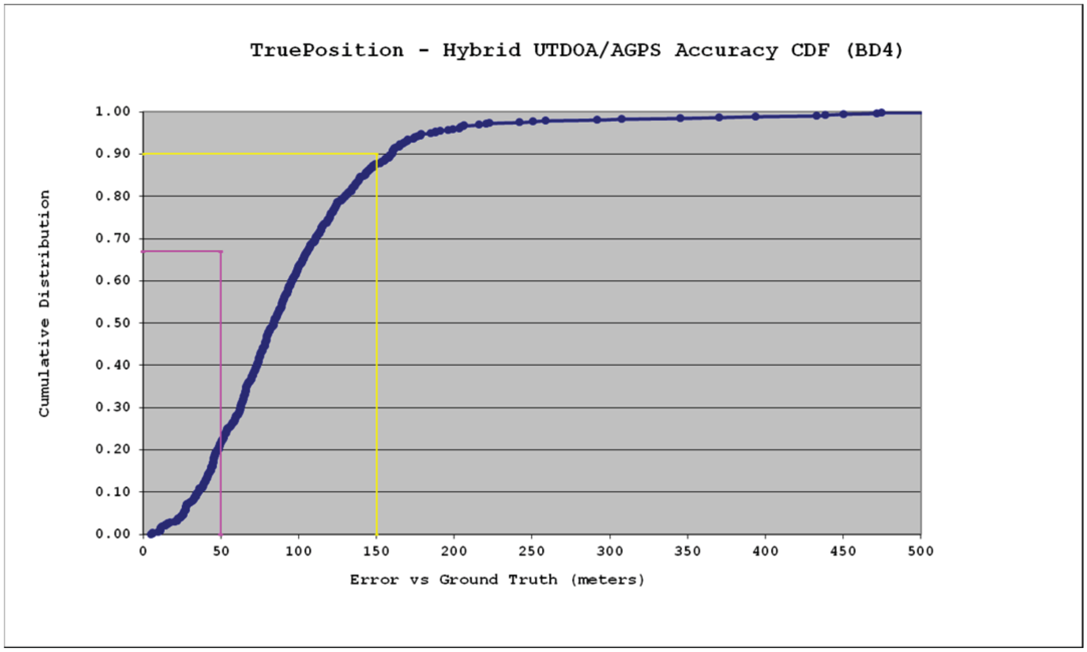

Figure 7.2-5. Bldg. 4 - Hybrid UTDOA/AGPS Accuracy CDF

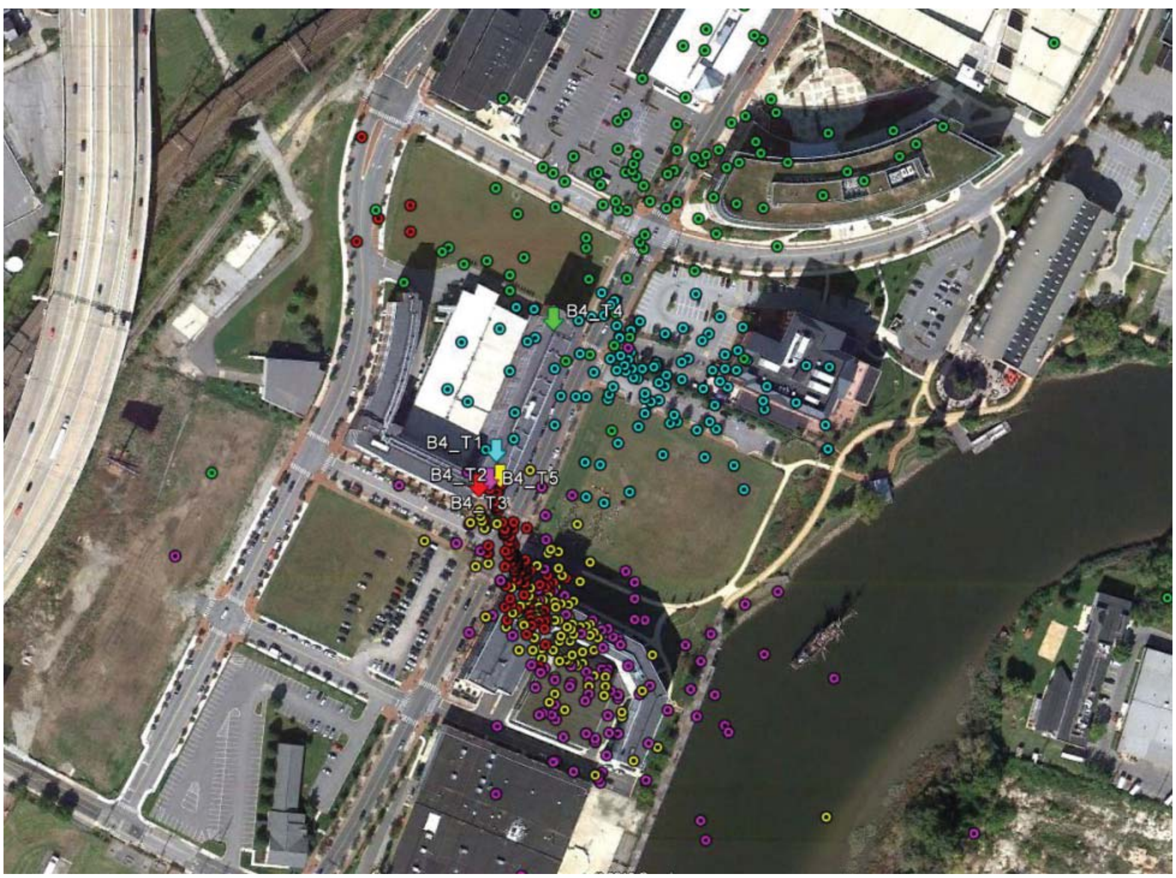

Figure 7.2-6. Bldg. 4 - Hybrid UTDOA/AGPS Location Scatter

7.2.4 Bldg. 8: Iron Hill Office Bldg., Newark, DE

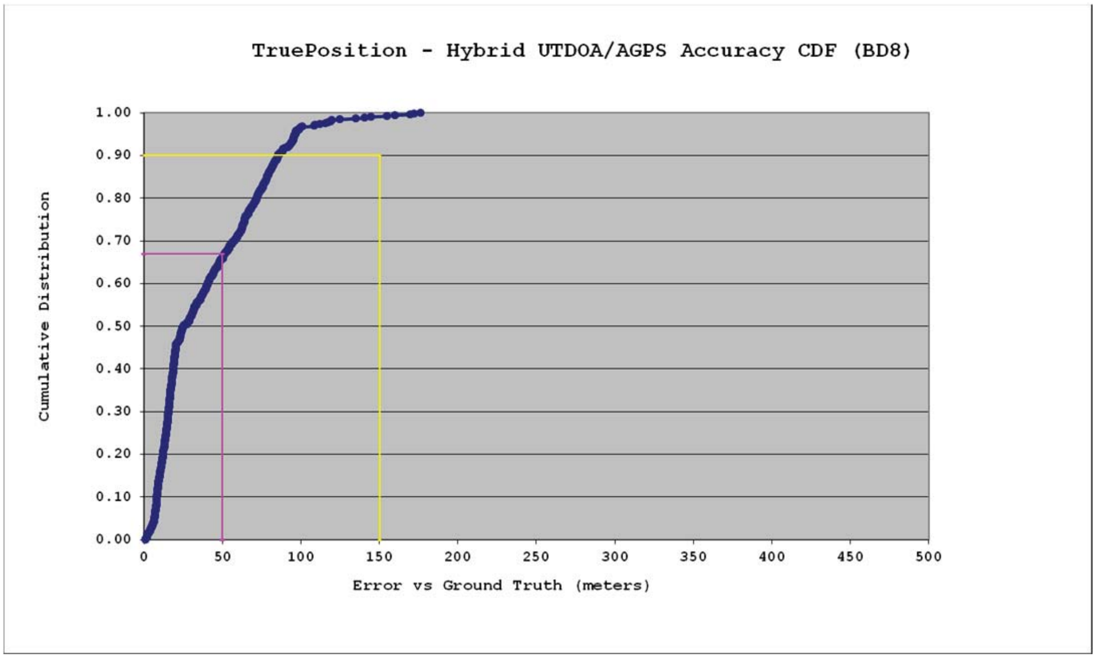

Figure 7.2-7. Bldg. 8 - Hybrid UTDOA/AGPS Accuracy CDF

Figure 7.2-8. Bldg. 8 - Hybrid UTDOA/AGPS Location Scatter

7.2.5 Bldg. 10: 2-Story Brick Building, Brandywine St., Wilmington, DE

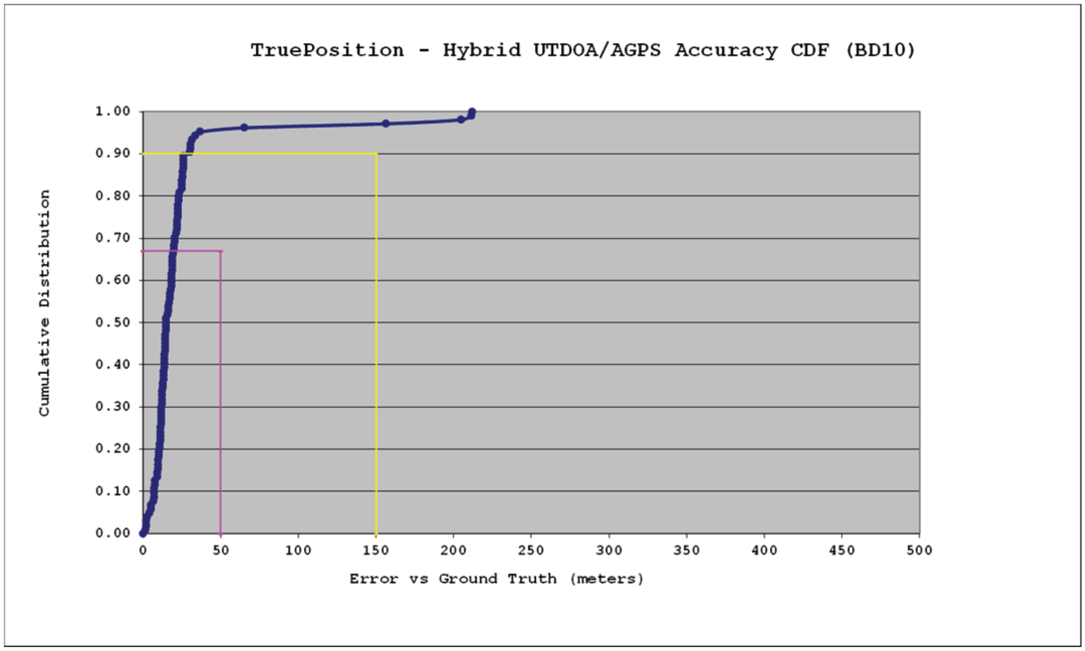

Figure 7.2-9. Bldg. 10 - Hybrid UTDOA/AGPS Accuracy CDF

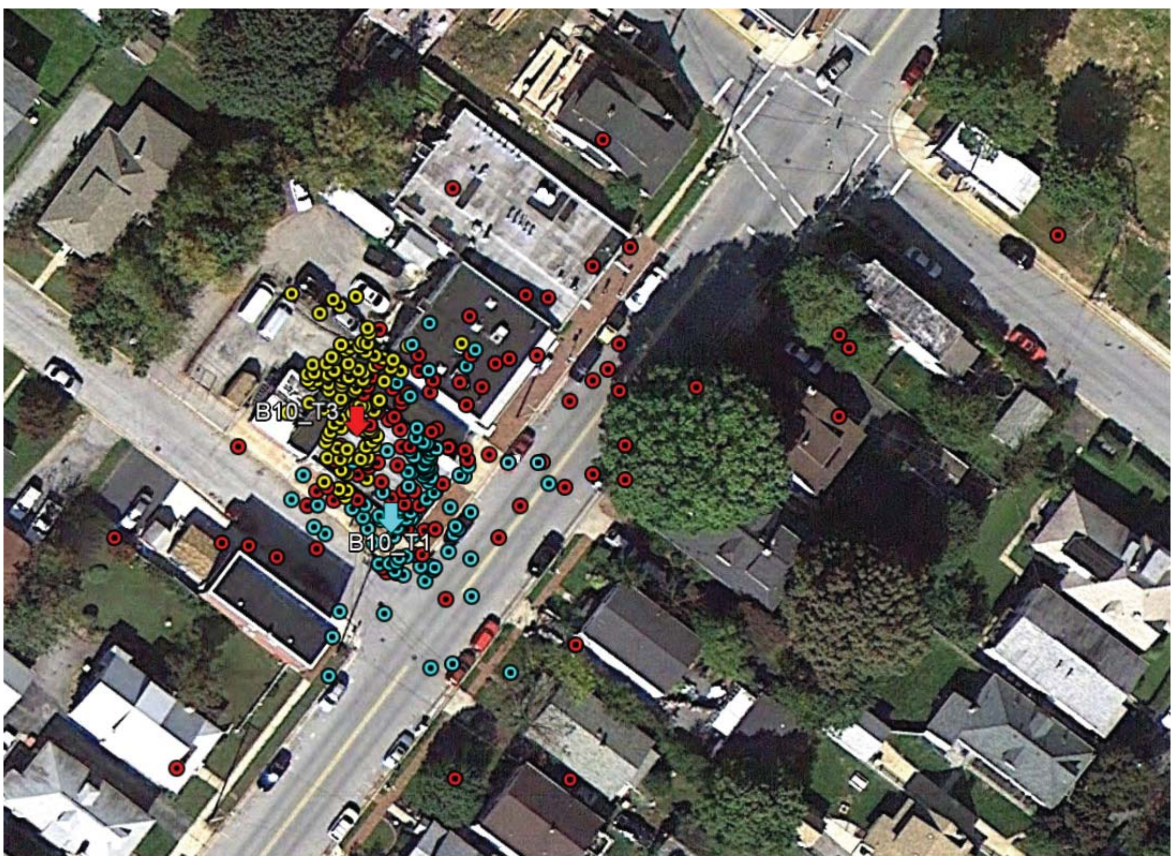

Figure 7.2-10. Bldg. 10 - Hybrid UTDOA/AGPS Location Scatter

8 Summary Observations and Conclusions

TruePosition's UTDOA is a proven location determination solution widely used to meet the requirements for outdoor E911. The same is true of AGPS, which excels in many situations were sky visibility is not severely hampered. TruePosition has added an AGPS component to augment and further enhance the performance of UTDOA. This hybrid combination was tested extensively in Wilmington, DE.

Overall, the Hybrid system performed well indoors. Notably, very few outliers were observed, with well over 95% of test calls with errors below 200 m. In all cases the yield was extremely high, close to 100%.

The summary results in the form of the CDF plots for each building provided in Section 7 above shed further light on the observed performance characteristics of the UTDOA/AGPS hybrid solution.

It can be seen that the solution performs best in smaller buildings in suburban settings. This is to be expected since the improvement brought by AGPS in that case tends to dominate the hybrid performance. An example of this performance is seen in buildings 1 and 10, which are both two-story brick structures. Composite CDFs that are neatly packed near the y-axis signify that very good performance.

Larger suburban buildings with ample space around them, if they are not tall or particularly heavily built, are next in the quality of overall performance, for example Building 8, a 3 story office building. Similar performance can be obtained in mid-sized urban buildings if they have adequate spacing, as in the lighter urban parts of the urban environment, e.g., Building 9, a 4-story brick and glass building.

A heavily built taller residential building, even with ample spacing around it, e.g., Building 4, a large 7-story residential mid-rise, can be a challenging environment. Location fixes are seen scattered over a larger distance including other similar buildings separated from the intended building. Performance in this case tends to be dominated by UTDOA and the resulting performance is roughly consistent with established outdoor UTDOA performance.

Equally challenging, naturally, are large urban buildings surrounded by similar structures. The presence of UTDOA in the hybrid, however, prevents performance in those situations from severely degrading, as would be the case had AGPS been operating on its own. Examples of this are Buildings 5 and 6, both high rises in the center of Downtown Wilmington and Building 3, a 9-story hotel in the urban area.

A phenomenon seen in the Bay Area testing with good terrestrial multilateration is seen here as well but to a significantly lesser extent. This is the phenomenon wherein the multilateration solutions (be it forward or uplink) are shifted due to dominant reflection from large buildings, whether across the street or a block or two away. Building 9 provides such an example where a mid-sized urban building has large reflecting buildings in its vicinity. The addition of AGPS to UTDOA (assuming the building is not very heavily constructed or in the middle of high clutter) improves the overall solution and decreases error shifts due to large building multipath.

A minor issue identified from the test results pertained to the reliability of the reported uncertainty estimate. The reported uncertainty often does not match the expected 90% confidence (i.e., % of calls with empirically measured error < uncertainty radius is considerably lower than 90%). This has been observed even if the error performance is relatively good. This is seen for example in buildings 7 and 9 in the urban area and 2 and 8 in the suburban area. This issue merits some attention from TruePosition.

Finally, several of the scatter diagram plots in Section 7 point to a conclusion similar to what was observed in the Bay Area, which is that even when the location system is working well it is hard to pinpoint with confidence the building from which the emergency call was made—let alone the suite or specific room. Examples of this are commonly seen in the urban area, e.g., Buildings 3, 6, 7 and 9 in the urban area. More indoor-specific hybrid solutions may have to be developed and deployed to reach such a lofty goal.

In conclusion, the Hybrid UTDOA/AGPS solution from TruePosition have been demonstrated to work and provide useful outputs to aid in locating the caller when the caller is inside a wide variety of buildings in both the suburban and urban environments.

The results and findings in this report are provided to the FCC so it can consider them, along with other sources of data, like the results from the CSRIC III sponsored testing, in its comprehensive evaluation of the indoor performance of existing and emerging wireless location accuracy technologies applicable to E911.

Appendix A: Performance Results Per Test Point

Appendix A is provided in a separate document/file due to size considerations.